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Orbit Analysis Tools Software for the Macintosh (Version 5) Users Manual

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13. ABSTRACT (*Maximum 200 words*)

The Orbit Analysis Tools Software (OATS) program has been revised and expanded. The program's function is to perform satellite mission and coverage analysis using numerical and graphical techniques to analyze and display earth coverage data and ground-to-satellite geometrical parameters. Satellite ephemerides can be computed by any one of four orbit propagators provided with the program or imported from an external source. Six commonly utilized map projections are available to plot computational results. Some of the program enhancements for version 5 include accommodations in all aspects of plotting and coverage analysis for non-nadir pointing satellites, comparison functions for graphical coverage plots, coverage snapshots, boresight plotting, improved user control of layer plotting, position and attitude computation functions, multiple target icon selections, plotting of map coordinates and satellite track time tags, and streamlined data interfaces. The program is written in FORTRAN utilizing DynaFace (a revision of the software used for OATS version 3) program interface software. OATS is designed to run on a Macintosh personal computer.

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ORBIT ANALYSIS TOOLS SOFTWARE FOR THE MACINTOSH (VERSION 5) USERS MANUAL

SECTION 1 - INTRODUCTION

This document provides a user's manual for version 5 of the Orbit Analysis Tools Software (OATS) program. OATS is a mission planning and analysis tool for Earth-orbiting satellites. OATS evolved from a collection of software tools developed by the Astrodynamics and Space Applications Office of the Naval Center for Space Technology, located at the Naval Research Laboratory in Washington, DC. The program and attendant documentation (References 1 and 2) has gone through two previous versions that were made available to the public; hence, version 5 is the third public generation of OATS software.

OATS is a single integrated program that runs on a Macintosh computer. It supplies a dualistic analytical environment, providing graphics-oriented analytical tools as well as tabular output that can be used to address many of the questions commonly posed by designers planning a new satellite system or by managers wishing to assess the performance of an existing system. OATS particular strength is the quantification of satellite coverage available from a user-defined configuration of satellites.

This manual is intended to provide an overview of OATS that will permit potential users to determine if the program meets their analytical needs. It discusses all program functions, shows how to access the various capabilities of OATS, and presents what the user should expect to see when the program menus and options are exercised. If additional discussion of program uses and functions are desired, the user is recommended to Reference 3. To complement its overview function, this manual is organized to provide fast access to information on single program capabilities. OATS is user-friendly in the accepted Macintosh fashion and many users may not require documentation; however, this manual will provide fast access to many of the details of program operation and will discuss strategies for efficient use of the program.

OATS major analytical capabilities and outputs include:

- Computation of pass parameters for a satellite and ground station, including azimuth, elevation, range, and range rate as a function of time, the times of acquisition of signal (AOS) and loss of Signal (LOS), and signal attenuation.
- Computation of coverage statistics for a set of targets under a system of satellites with user-defined attitudes using an optional set of ground stations for communication links. Statistics include rise and set times, duration of coverage, outage, and revisit times, and maximum, minimum, mean, and standard deviation of coverage, outage, and revisit times.

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- Computation and display for a system of satellites and ground stations of coverage data on a global grid. Display can be as a contour mapping of coverage isochrones or as a density mapping of regions of equal coverage. Capabilities exist for comparison of multiple sets of graphical coverage data.
- Creation of global maps, using a selection of two- and three-dimensional map projections.
- Creation of satellite ephemeris data, using a selection from four different orbit propagators and six orbit element data set formats. Provisions exist for fast display and inspection of ephemeris files.
- Display satellite geographic data, including position, field-of-view (FOV), ground tracks, and coverage swaths.
- Compute and display the overlap of instantaneous multiple satellite FOVs, defined in OATS terminology as snapshots.
- Display ground geographic data, including target and ground station positions, ground station fields-of-view (FOV), and Earth shadow data.
- Display of all mapped data with user-controlled colors, line widths, shading densities, and icon sizes.

Users should be aware that OATS employs the DynaFace software (Reference 4) to build its fundamental working Macintosh foundation. DynaFace makes possible all the basic types of environmental elements like graphics display windows, dialogs, and editors, as well as a fast, clean interface to most Macintosh toolbox utilities. In virtually all cases it is unlikely that users will notice DynaFace at all.

This manual will presume familiarity with basic Macintosh operations, including features like use of the mouse, selecting program functions with menus, setting program parameters and options with dialogs, and the standard Macintosh file interface dialogs. Users should also bear in mind that in typical Macintosh fashion OATS provides a working environment with a multitude of choices and analytical pathways, rather than a linear program with a narrow and well-defined set of inputs and outputs.

Section 2 provides information about software distribution and operating requirements. Section 3 discusses the design philosophies behind OATS and Section 4 is an overview of the OATS system. Both of these sections are general, high-level views of OATS' conventions, capabilities, and operating environment. Section 5 contains a discussion of all menu commands used to control and change the OATS operating environment, including window control parameters and printing. Section 6 explains the use of each of the orbit propagators and the generation of ephemeris data. Section 7 is a lengthy chapter because it discusses in detail the many plotting functions available to OATS users. Much of the program's analytical techniques are explained in Section 8, which shows how to perform the various satellite coverage analyses. Section 9 discusses the opening and inspection of ephemeris files and satellite attitude files, which are required for most of the analysis available through OATS. Section 10 discusses the format of self-generated and

external files. Section 11 is the last chapter--it presents a sample introductory session that can be used as a quick-start training exercise for beginning users. Three appendices provide supplemental information. The satellite antenna pattern definitions are contained in Appendix A. Appendix B contains helpful tips regarding processing of data with OATS, and Appendix C provides a review of the definition of orbital elements.

SECTION 2 - DISTRIBUTION DISKETTE

OATS runs on a Macintosh computer under System 7. The OATS executable program and related files are contained in a self-extracting archive file on a single high density 3.5 inch diskette, which may be obtained from the authors. Alternatively, the program is available over the Internet via the homepage of the Naval Research Laboratory,

http://www.cmf.nrl.navy.mil/

or directly via the OATS Internet address,

http://ssdd.nrl.navy.mil/www/oats/oats_welcome.htmlx

Versions of the software have been created to run with the Macintosh 88030 central processor unit (CPU) using a math co-processor, with the 88040 CPU, or with the Power PC. Interested users should specify which CPU they will be using to run OATS when they request a copy of the software.

OATS requires three megabytes of memory for minimal function; however, many of the graphics procedures require added memory. Experience has shown that OATS runs more efficiently if at least five megabytes of memory is made available. No additional files beyond the executable are required to run OATS; however, eleven small example data files are provided to assist the beginning user in gaining familiarity with OATS. The use and content of these files is discussed in Section 11, which provides a quick-start training exercise on the use of some of the major features of OATS.

SECTION 3 - PROGRAM DESIGN PHILOSOPHIES

Every piece of software comes with some set of inherent design philosophies and approaches to problems. In principle these design issues should be transparent to the user as much as possible, but in practice some aspects of program construction will show through. OATS is no different. This section presents a collection of design issues which impact on how the user approaches execution of the software. It would be helpful to keep these issues in mind when using the program.

3.1 IMPORTANCE OF EPHEMERIS FILES

The OATS program combines orbit propagation models with numerical and graphical coverage analysis algorithms. The design philosophy of OATS has been to separate the orbit models from the analysis processes. The reason for selecting this architecture is so that an arbitrary number of different orbit propagation codes can be added to the program without affecting any of the analysis codes. Thus, when doing mission analysis with OATS the user must always have satellite ephemerides available before proceeding with any of the coverage analysis functions. OATS is engineered to generate ephemeris files using a variety of orbit propagation models, and it is expected that a typical user will employ the OATS orbit propagators to generate ephemerides prior to performing analysis; however, OATS is also capable of employing imported ephemeris files if they use a prescribed format. The only difference between use of internally generated ephemeris files and exported ones is that processing will be slightly faster for the internally generated files.

3.2 LAYERING

When OATS creates graphics plots, it uses a layering technique similar to such programs as MacDraw (Reference 5). For example, a map drawing (see Section 7.3) can consist of as many as five layers of drawings when it is first created. The on-screen appearance is very much like stacking a set of transparencies for a projector. These layers are maintained as a list, with each layer receiving a unique name assigned by the OATS program. The program also provides a set of tools that allow the user to view and manipulate the list elements. For example, at the user's discretion some subset or the full set of the layers involved in a generated map can be "glued" together into a single layer. Alternatively, the list of layers could be maintained separately and manipulated via program tools. Separate layers can be moved forward or backward in the list, or deleted as necessary. Plotted items can usually be immediately erased from the drawing without impacting other previous layers in the drawing; however, the user should be aware that a few circumstances dictate that an immediate erasure will eliminate all layers.

As examples of the usage of layers, consider that a simple plot of a list of targets (see Section 7.5) is a single layer that can be moved in the layer list, removed, or re-drawn as often as needed to get it correct. On the other hand, if a zoom process on a target layer superimposed on a map is exercised (see Section 7.4.1), most users will "cement" all plotted layers together before the zoom. Because only the top layer gets enlarged, performing a zoom without a combination would enlarge the targets and not the map--thus losing the background information provided by the map. Once compounded, layers cannot be separated, implying that if the layer of plotted targets is subsequently found to be in error, the entire plot must be redone to correct the problem. One of the ramifications of the layering approach is seen whenever it is necessary to reconstruct the screen, for instance when a dialog is temporarily shown over top of the graphics window. The screen is re-drawn one layer at a time. If there are many layers, this can become time consuming.

3.3 <u>DATA CHECKING</u>

OATS performs checks of entered data; however, modifications to the user entered data by the program are minimal. Unusual entries are flagged and an ALERT is displayed, but usually no attempt is made to alter or "fix" the data. In the isolated cases where OATS tries to implement a "fix", the user is conspicuously notified. Otherwise, any unusual data entries are carried along after an ALERT is given. It is the obligation of the user to correct them. Choosing to ignore an ALERT may cause generation of incorrect or invalid data, or may cause a program crash.

3.4 <u>WORK FILES</u>

OATS uses scratch space work files for some processes. During the course of a normal program execution, these files are deleted and the user doesn't see them or have to deal with them. Abnormal endings of program execution may result in leftover files that the user may wish to delete. These files can be identified because they are created in the directory from which OATS is launched and bear a "TEMP." prefix. If space is severely restricted on the user's computer, there may also be system generated error conditions if the scratch files overflow storage capacity.

SECTION 4 - OVERVIEW OF THE OATS SYSTEM

This section presents an overview of the OATS software. It discusses the OATS high level menu system, menu display conventions, dialog display conventions used in this manual, and windows used by the program. Detailed information on the various menu options and dialogs available through OATS can be found later in this manual in Sections 5 through 9.

4.1 OATS MAIN MENU

Figure 4-1 shows the OATS Main Menu as it appears when the program is initiated. These menu selections are broken into two groupings. The first group is covered in Section 5, and includes all menu items geared toward control and definition of the OATS operating environment. These menu items include:

- **Apple** ( ) - Provides access to overview functions associated with OATS.
- **File** - Provides functions used to manipulate files associated with OATS.
- **Edit** - Provides most normal Macintosh editing functions, some of which are applicable to graphics windows as well as to the text editor windows.
- **Window** - Provides controls for manipulation of and definition of windows used by OATS.

	File	**Edit**	**Window**	Propagate	Plot	Coverage	Data

Figure 4-1. OATS Main Menu

The second group is covered in Sections 6 through 9, and includes the analysis tools used by OATS to perform orbit and satellite coverage analysis. Note that these menu options will appear as a different color than the environment options. These menu items include:

- **Propagate** - Provides functions required to generate ephemeris files, including access to and display of orbital elements.
- **Plot** - A large menu system that gives the user the ability to define and execute graphics plots of satellite orbits and coverage information.
- **Coverage** - Provides access to the analytical tools that generate information related to satellite coverage and visibility.
- **Data** - Provides functions required to open existing ephemeris and satellite attitude files for use by OATS processes or to preview existing files.

4.2 MENU DISPLAY CONVENTIONS

As is common in Macintosh applications programs, selection of any of the menu items shown in Figure 4-1 will yield an additional list of menu items--some of which themselves will also yield sub-menu lists. In this manual, the conventions used to show the result of selection of a menu item are characterized in the sample menu shown in Figure 4-2. As shown in this sample:

- **OptionA. . .** shows a dialog used to set execution parameters
- **OptionB** ▶ produces a sub-menu of choices
- **ActionA** executes a process
- **ActionB** ⌘H executes a process just like **ActionA**, but which can also be executed without using the menu system by entering the two keystroke **⌘-H** command-key

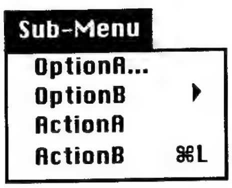


Figure 4-2. Sample Menu Display

4.3 DIALOG DISPLAY CONVENTIONS

Figure 4-3 presents an idealized OATS dialog. Dialogs in this program utilize most of the standard tools available in Macintosh user interfaces, such as command buttons, static text and static pictures, on/off checkboxes, mutually exclusive radio buttons, and control scroll bars to allow selection of a value on a scale between fixed endpoints. Whenever any such item in a dialog is mentioned specifically in the text of this document, the convention will be to italicize the item (e.g. *Standard Macintosh Checkbox*) to make clear that an individual dialog item is being singled out.

There are several dialog display devices that are peculiar to this manual, and which are also shown in Figure 4-3. These include:

- Program Generated Data - These fields show locations where OATS will provide information to the user, and for which the program has control of what is displayed. Dialogs are shown with a representative value in place in these fields. Actual displays will of course depend on the various program settings elected by the user.
- User Supplied Data - These fields allow data to be entered by the user. Typically the program will supply some type of default or previously assigned data. The user's data is entered by using the mouse or the **TAB** key to place the cursor in the desired field before typing in data. OATS displays

of this type will contain a number for both numerical entries and for text entries indicating the expected maximum number of digits which the user should use to enter data into this field.

- Overlying Sub-Dialogs - In some cases, overlying dialogs are used such that a dialog is used to enter data complementary to the large dialog interface upon which it is shown superimposed. The location of the overlying dialogs is shown by a hatched rectangle.
- Lists of Objects - These are also shown with a few representative elements in place. In cases where some other aspect of the dialog is directly dependent on which member of the list is selected, a member of the list is shown highlighted.
- Transient Pictures - In a few cases, transient pictures are drawn within dialogs. The locations of these items are shown in the dialog in which they are drawn.

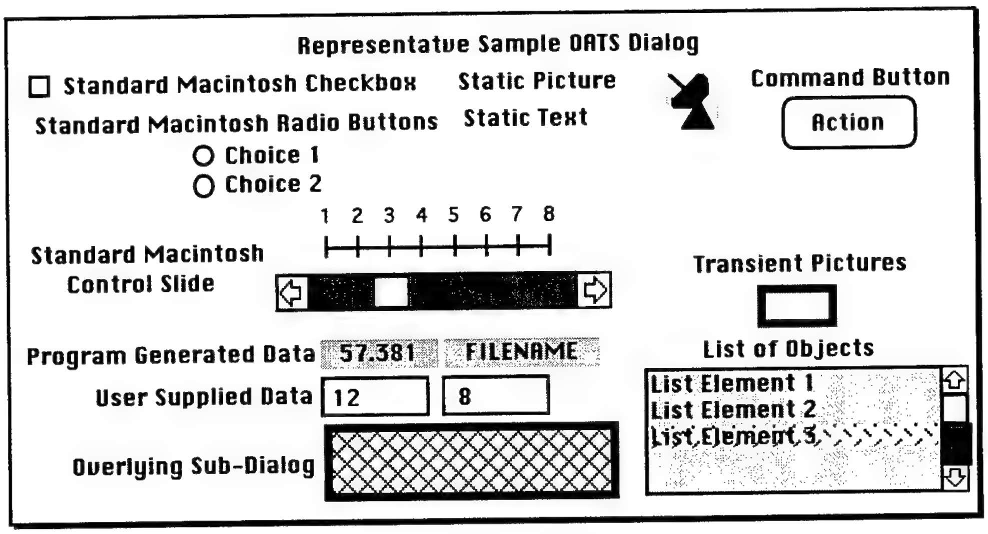


Figure 4-3. Sample Dialog Display

There is one additional dialog display convention that is pertinent to all dialogs. As with many Macintosh programs, OATS often provides a series of dialogs that are nested in a tree structure and called from other dialogs. It is a useful mechanism for subdividing the organization of data entry and display. In order to remind the user how deep the current active dialog lies. into the dialog nesting, a color scheme is used. All colors are pastels so there is no problem if a user is operating the program in a black-and-white environment. From most shallow to deepest, the nesting colors are blue, yellow, green, and red.

4.4 <u>OATS WINDOWS</u>

OATS utilizes four work windows, the controls for which are discussed in Section 5.4. These windows include the following.

4.4.1 GRAPHICS WINDOW

Due to the graphics-oriented approach of the OATS program, this window is unquestionably the most important. It is also the default window that is opened when the program is initiated. It is a full-view unity-scale graphics window used for all OATS mapping, orbit plotting, and coverage contouring activities. It should be thought of as the local active drawing window, even though it may not show all objects in the plotting region. DynaFace provides a single drawing area (i.e. plotting region) which has maximum dimensions of 30,000 by 30,000 pixels, and which can be divided into many pages if required. It is extremely unlikely that any OATS user would ever require anything even close to such a large drawing area. Memory demands for such an area would also be difficult to accommodate. Seldom is more than one page needed, and multiple pages can be confusing to unpracticed users. Most commonly the drawing area, the Graphics Window, and the screen size are equivalent and are set to dimensions that are in the range of a few hundred to perhaps a thousand pixels on a side and are undivided (i.e. single page). This typically supplies all the resolution needed for OATS problems. However, there may be some circumstances where OATS will employ a drawing area that measures a few thousand pixels on a side (for example, see Appendix B). Since the typical Graph Window must still conform to screen dimensions that are a few hundred pixels on a side, only a modest percentage of the drawing area would be visible at any given time. Consequently, it could be difficult to keep track of what has been plotted. For this reason, the Graphics Window has two settings--a full-view used for the majority of normal plotting and a reduced-view for viewing large plot areas. The reduced-view echoes the full-view Graphics Window; however, at a significantly smaller scale so that the entire plotting area is visible. Because of the scale compression, clarity is compromised in order to provide a comprehensive view. The reduced-view function is most helpful if the user elects to use multi-paging of plots where not all plotted data is visible in the Graphics Window. This setting is scaled according to settings in the window set-up controls (see Section 5.4.3).

The Graphics Window is a standard Macintosh window, as depicted in Figure 4-4. The only in-window controls are the close box in the upper left title bar, the grow box in the upper right title bar, the scroll bar controls along the bottom and right sides of the window, and the size box in the lower right corner.

OATS draws plots in the Graphics Window within a highlighted plot frame, a rectangular area with a solid line defining its edge. If moving or resizing the plot frame, the edge becomes broken and moving in the usual sense of a Macintosh marquee. It is common to allow the plot frame region to be defined by the full-open Graphics Window, in which case the edge of the plot frame is not seen. However, plots can be made in subsets of the Graphics Window by defining a reduced plot frame. The plot frame is most easily defined in a Graphics Window by clicking and dragging the mouse to the desired size. If some figures exist in the window, the command key (⌘) key must be pressed and held while clicking and dragging. The command

key is also often known as the Apple ( ) key. Selective definition of the plot frame can be used, for example, to define multiple plots side-by-side for comparison purposes. It is also possible to define the plot frame within the reduced view in a similar fashion, because the plot frame will be echoed in the full view. Although OATS users will not typically make use of the capability, DynaFace makes it possible to define an n-by-m multi-page drawing area (see Section 5.4). All pages are shown in the reduced view. Using the plot frame also allows plots to be defined across page boundaries.

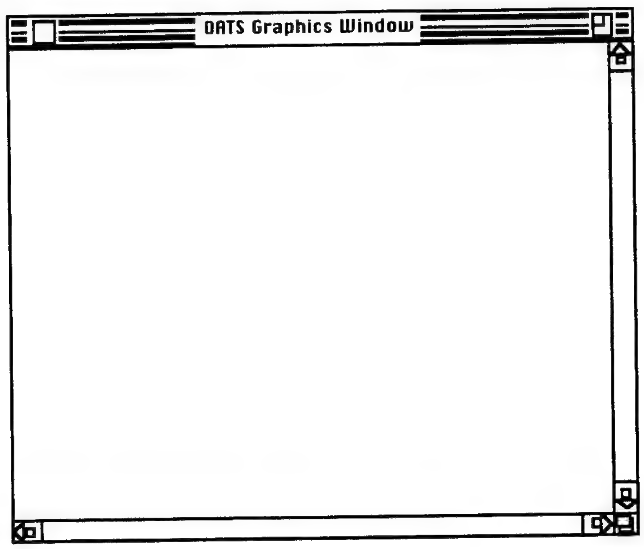


Figure 4-4. OATS Graphics Window

4.4.2 GRAPHICS TOOLS

The Graphics Tools Window shown in Figure 4-5 is a convenient way to manipulate the various plotted layers that are viewed in the Graphics Window. Principle information content consists of a count of the number of layers and a numbered listing of layer names. Names are always unique per execution of OATS. Every possible plot is assigned one of a discrete set of plot layer names combined with a counter for that type layer, allowing multiple plots of the same type that will still have a unique name. This is considered essential for users that need to manipulate the layers and know which layers they're working with. Note that layers are displayed back to front, with the top layer having the highest layer count number. Supplemental information shows memory status readouts.

Controls in the Graphics Tools Window allow the user to manipulate plotted layers at will. The *Back to Front* and *Front to Back* buttons move the single top and bottom layers accordingly. The mouse can be used to select single layers from the layers list. If used in conjunction with the **SHIFT** key, the mouse can be used to select a consecutive series of layers. The *ALL* and *NONE* buttons permit quick selection or deselection of all layers. *DELETE* will remove all selected layers from the plot, and *COMBINE* will

combine selected layers into a single layer with a new name. Once layers are combined, they cannot be separated. The *FORWARD* and *BACK* buttons will operate on any single selected layer and move it in the layer stack. It is possible to do similar manipulations without use of the Graphics Tools Window by using menu commands (see Section 5); however, menu commands are far less convenient because it is difficult to keep track of where the various layers lie in the stack. The *RENAME* button also operates on a single layer, and will rename that selected layer according to the user's input to the editable text box next to the button. The Graphics Tools Window has only a close box in the title bar, because it is maintained with fixed dimensions.

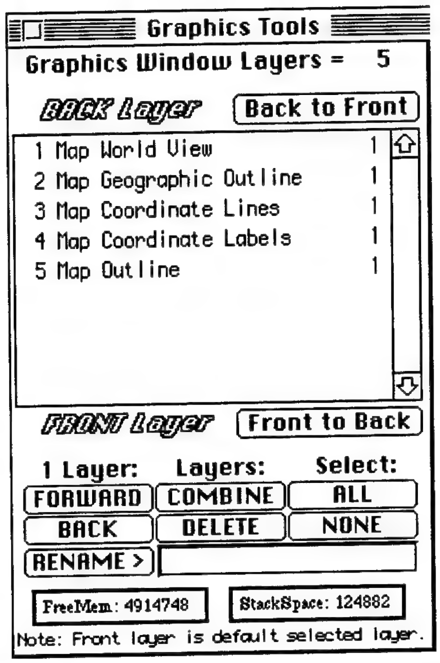


Figure 4-5. OATS Graphics Tools Window

4.4.3 TEXT WINDOWS

OATS utilizes two editor-type windows, called the Volume Text Window and the Normal Text Window. These are primarily used for immediate display of tabular data during generation by OATS analytical functions. The user can perform many of the standard types of functions common to editors for data displayed in these windows (e.g. search for text strings or print selected sections). It is often convenient to use these windows as a text editor; however, it is best advised to do so for small items to avoid the task of opening an external editor or switching back and forth between OATS and another editor. The principal differences between the two windows are that the Normal Text Window will only handle data sets of 32,000 characters, while the Volume Text Window has an essentially unlimited capacity. Because of the capacity issue, when a previously generated OATS text file is used to open the program, the data is

defaulted into the Volume Text Window. The Normal Window does have an advantage over the Volume Window in that it is possible to alter the individual font characteristics, whereas the Volume Window is fixed with an unstyled black Monaco font. Only font size can be changed--controls exist in the Window menu (see Section 5.4.3). Volume and Normal Text Windows are shown in Figures 4-6 and 4-7. The Volume Window is an ordinary Macintosh window, and has only standard close, grow, and size control boxes. The Normal Window also has those controls, but in addition has a pull-down menu for *Text Style* shown in Figure 4-8.

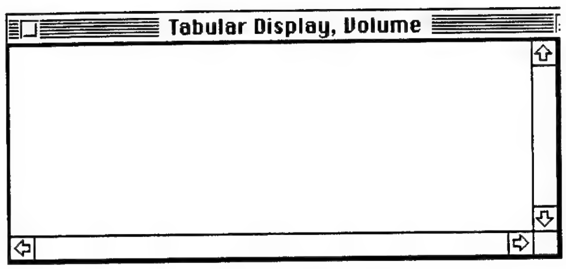


Figure 4-6. Volume Text Window

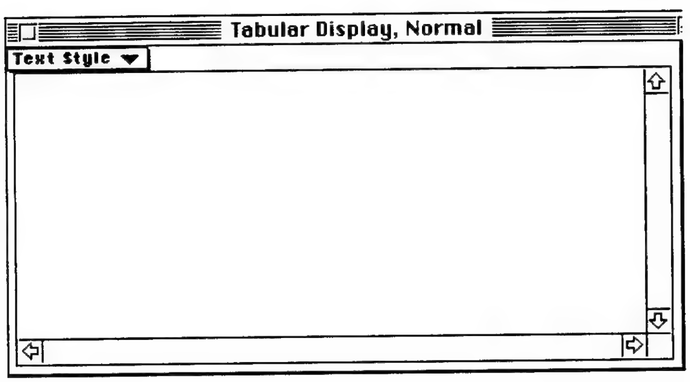


Figure 4-7. Normal Text Window

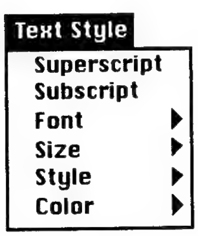


Figure 4-8. **Text Style** Pull-Down Menu for Normal Text Window

4.4.4 OTHER WINDOWS

OATS utilizes a variety of other windows at various points in its execution; however, these are not work windows. They are completely under the control of the OATS program and the user has minimal interaction with them.

SECTION 5 - ENVIRONMENT MENUS

This section describes the behavior and performance of the OATS menu items that deal with the system's operating environment. The relationship of these menu selections to the OATS system menu were briefly described in Section 4.1. These selections include those which are largely under the control of the DynaFace utility, and which have direct counterparts in most Macintosh-styled software. For OATS, this complement of environment menus includes the **Apple**, **File**, **Edit**, and **Window** main menu selections. A characteristic of many of the environment menus to which the user should pay special attention is that some menu selections are inactive depending upon whether the Graphics Window or an editor-type window (see Section 4.4) is in front. The front window is referred to as the active display.

5.1 APPLE MENU

Figure 5-1 shows the sub-menu produced by choosing the **Apple** ( ) menu. These menu selections deal with program overview functions and with parameters that affect the full OATS program.

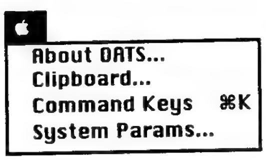


Figure 5-1. **Apple** Menu for OATS

About OATS

This command produces an informational display similar to that seen in Figure 5-2. It provides information such as program authors and address, but most importantly it provides the version number and date for this copy of OATS. This display is exited by clicking anywhere inside the display.

Clipboard

This command shows the user the current contents of the clipboard, in a display similar to that seen in Figure 5-3. The large clip-window (empty in the example shown) may contain anything normally supported by Macintosh clipboard functions, including text and graphics. Readouts above the clip-window display the largest block of contiguous free heap memory, current stack space, and the total free heap memory as aids to program function. This display is most useful as a means of verifying information that is being imported into or out of OATS. It is usually exited by clicking inside the box for the large clip-window or pushing a keyboard *Return*. This exit technique leaves the clipboard contents undisturbed. An option *Clear* button allows the user to

exit the display and simultaneously clear the contents of the clipboard. The clipboard display has a grow box in the lower right corner to allow the user to view more of the clipboard as required.

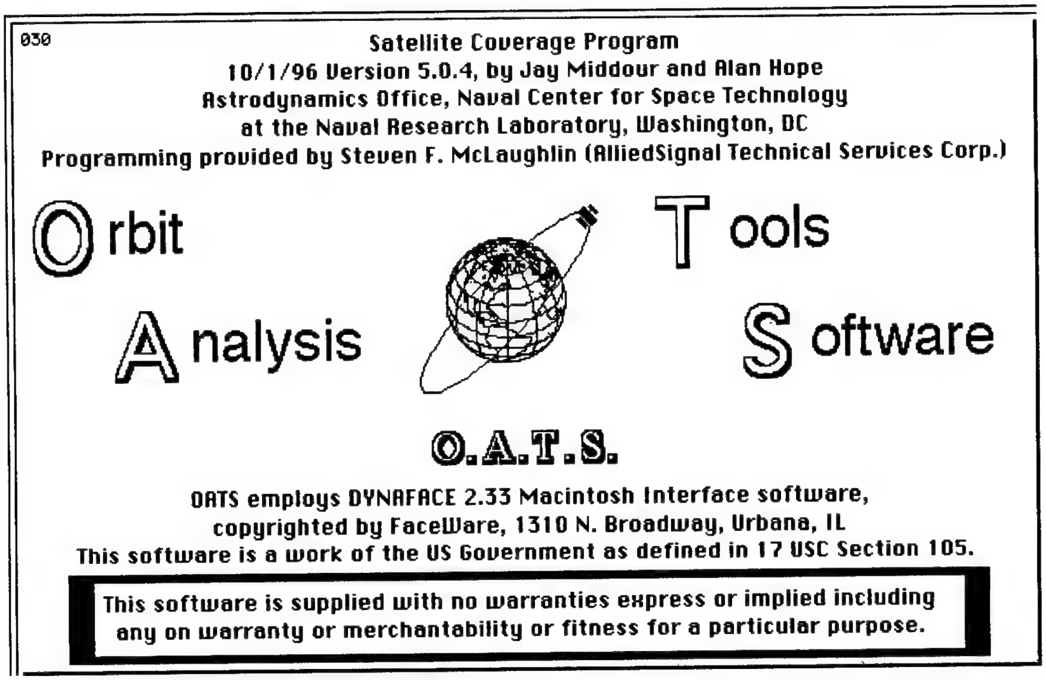


Figure 5-2. Informational Dialog on OATS

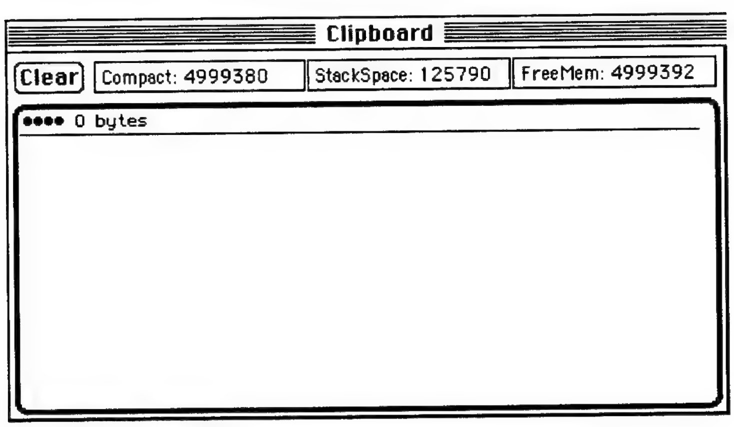


Figure 5-3. Clipboard Dialog in OATS

Command Keys

This command produces an informational display similar to that seen in Figure 5-4. Like most Macintosh programs, OATS allows the use of two-stroke command-key sequences to produce the same results as some of the high-use menu selections. This display presents a single-glance review of the available command-key sequences for OATS. The display is itself available with the use of a **⌘-K** command. All command-keys will be noted in later sections of this document.

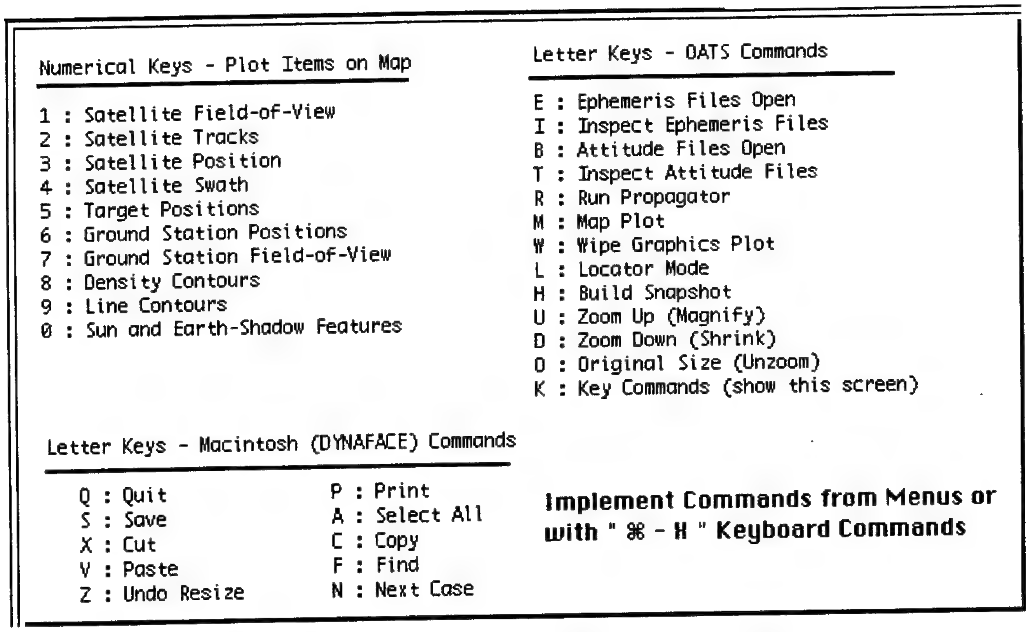


Figure 5-4. Summary of All OATS Command-Keys

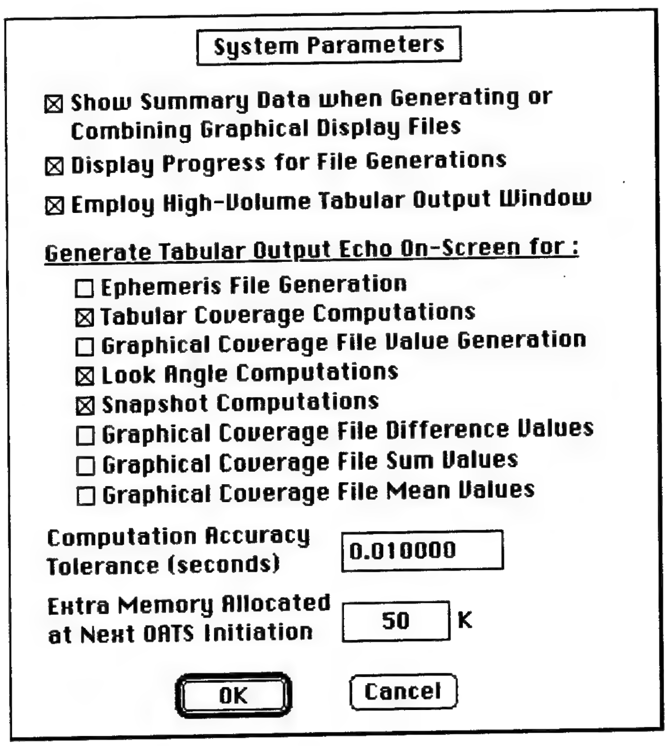


Figure 5-5. System Parameters Dialog

System Params...

This command provides a dialog as shown in Figure 5-5 that allows the user to set parameters that are used in more than one of the OATS analysis tools. The first parameter is an on/off flag controlling whether a status display of progress toward completion is presented when

computations are being carried out. This display consists of a bar graph that grows in real time, a numerical percentage, and the destination file name for the computation. There is some quantity of overhead associated with generating this display. When the user is generating files that are small, the wait time is also small and the display can be turned off to bypass the overhead and facilitate program execution. The second parameter requires an understanding of Section 8.2, but is used only as an on/off flag for a summary display. The third parameter governs whether on-screen tabular output appears in OATS' Normal Text Window or Volume Text Window (see Section 5.4). Next is a series of on/off flags dictating if on-screen tabular output is generated for various OATS processes. Typically some of these flags will be off (e.g. ephemeris file generation is usually lengthy and of little interest) and some will be on (e.g. look angle computations are sent to a file but it is usually interesting to view them on screen as they are generated). Computation accuracy within the OATS system can be set in the next-to-last option, and the final option allows the user to alter the stack space allocated by OATS the next time it is launched. Fine-tuning of this parameter is sometimes helpful.

5.2 FILE MENU

The **File** menu as seen in Figure 5-6 provides functions used to manipulate files associated with OATS. Most of these options are analogous to their counterparts in other programs run on Macintosh computers.

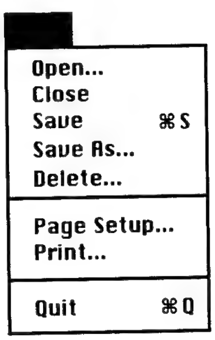


Figure 5-6. **File** Menu for OATS

Open...

The **Open** command is used to import picture files or text files into OATS, depending upon which window is foremost and active. If no window is open, this option is invalid. See also Section 7.3 on Standard Maps. **Open** is most useful for importing a foreign PICT file into the OATS Graphics Window to incorporate it as part of an OATS plot; however, an arbitrary text file can also be read into and edited using a text window.

Close

The **Close** command closes the window that is foremost and active, in the sense that the program associates a window with a file or is expecting to associate a window with a file. If no window is open, this option is invalid. See also Section 5.4 on OATS windows.

Save

This command provides the option of saving the contents of the current front window, either graphics or text. If a previous save of the material has not been performed, the action will be the same as for the **Save As** command. If the front text window is empty, this option will become invalid (grayed out). The OATS program-specific icons shown in Figure 5-7 are used to save text and graphics files. **Save** can be initiated with the command-key **⌘-S**.

Figure 5-7. OATS Icons for Text and Graphics Files

Save As...

This commands brings up the standard Macintosh interface dialog used to select the directory and file name for a new file. If the graphics window is empty, this option is invalid. See also the discussion in Section 7.3 on saving Standard Maps. If multiple layers are plotted in the Graphics Window, they will be combined into a single picture before the save process is performed.

Delete...

This commands brings up the standard Macintosh interface dialog used to select and delete a file.

Page Setup...

The standard Macintosh **Page Setup** interface dialog is presented, which allows the user to chose the paper type, size, orientation, and special effects that will be used when printing.

Print...

The standard Macintosh **Print** interface dialog is presented, which allows the user to choose the number of copies, page limits, destination, etc. before printing the contents of the active window. As usual, the **Chooser** command under the **Apple** menu is used to select a printer and **Print** can be initiated with the command-key **⌘-P**.

Quit

This commands ends the OATS program execution. There is a brief delay before termination because OATS saves most current program parameter settings for the next execution. During the delay, OATS presents a message notifying the user of the closure processes. Only a few parameters are defaulted for each program run. Quit can be initiated with the command-key **⌘-Q**.

5.3 EDIT MENU

Edit provides most normal Macintosh editing functions, some of which are applicable to graphics windows as well as to the editor windows. The **Edit** menu is shown in Figure 5-8. Although **Edit** provides most of the generic menu-originated editing commands, several edit-related commands exist that are specific to each of the OATS windows. These are discussed in Section 5.4. Commands issued from this menu for the Graphics Window typically act on the single top layer or on all layers in the Graphics Window.

Cut	⌘X
Copy	⌘C
Paste	⌘V
Clear	
Select All	⌘A
Search For...	⌘F
Next Case	⌘N

Figure 5-8. **Edit** Menu for OATS Windows

Cut

The **Cut** command (available as the **⌘-X** command-key) deletes an item which has been highlighted with the mouse for text data, or the top selected layer of the graphics display. The cut item is stored into the clipboard, from where it may be pasted into another application or into another area within the OATS window. One technique for removal of successive plotted layers is to utilize the **Cut** command, then clicking on the next layer to select it, and then using **Cut** once again.

Copy

The **Copy** command creates a copy of the highlighted text item for an editor window or a copy of the selected top layer of the Graphics Window, and then places it onto the clipboard. The copied data may then be pasted into another application, into another section of the drawing area in OATS (if graphics), or into another portion of the editor window (if text). This can also be initiated with the **⌘-C** command-key.

Paste

The **Paste** command is used to paste a picture or text that has previously been placed in the clipboard. The cursor can be used to select the location within text for a **Paste** . Graphic objects are pasted into the upper corner of the current frame area. The frame area will be either the full Graphics Window (the default case), or the user-highlighted frame area. **Paste** can also be done using the **⌘-V** command-key.

Clear

This command deletes selected text or selected graphics layer(s).

Select All

This menu selection can be used in graphics or text windows to select all plotted items or all displayed text prior to processing them with commands such as **Copy** or **Clear**. This can be selected with the **⌘-A** command-key. The menu selection appears as **Select All in Frame** if the Graphics Window is active.

Search For...

This command and the next apply to text windows and are inactive if the graphics window is active. **Search For** brings up the DynaFace dialog seen in Figure 5-9, which allows the user to search for and replace character strings. The OATS text windows are capable text editors, but are typically used only for text output. Consequently, the *Find* aspect is of most importance. It can be used for example to quickly locate the first occurrence of an output record in a lengthy tabular display with a particular time tag. This can be initiated with the **⌘-F** command-key. The *Replace* option is active only after a successful *Find.* This dialog also provides *Help* data and has several additional search/replace options available if the "-->" checkbox is marked; however, these options are seldom of relevance to OATS users.

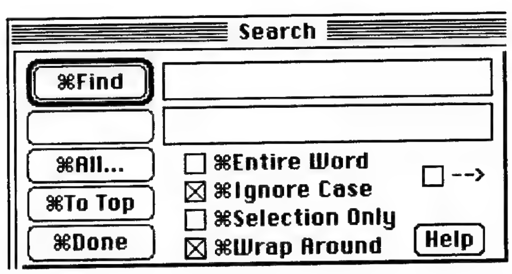


Figure 5-9. Search Interface Provided by DynaFace

Next Case

This command is used after the **Search For** command has initialized a character field that is being sought. It highlights the next occurrence of the string input in the **Search For** dialog box without the need to keep the *Search* dialog open.

5.4 WINDOW MENU

OATS makes use of four windows, which are described in Section 4.4. The **Window** menu provides the controls which allow the user to manipulate and define these windows as needed for his applications. The

available options include such choices as hide or display of windows, text window font characteristics, and dimensions of graphics displays. The base **Window** menu is shown in Figure 5-10. It is divided into three sections, grouped by function as discussed below.

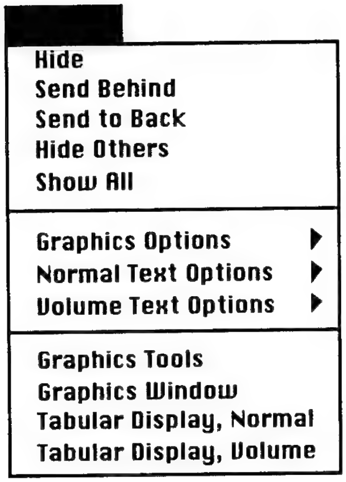


Figure 5-10. **Window** Menu

5.4.1 WINDOW STACKING COMMANDS

The first group of very simple commands are relevant to the locations of windows as they are stacked back-to-front on the display screen. The first four menu commands all relate to the front most and currently active OATS window.

Hide

This hides the front window from view--the contents are not altered.

Send Behind

The front window is moved behind the window second closest to the front of the display stack.

Send to Back

This command moves the front window to the rear of the display stack.

Hide Others

All windows except the front window are hidden from view.

Show All

This command makes all permanent OATS work windows visible.

5.4.2 WINDOW VISIBILITY COMMANDS

This is the bottom set of menu commands in Figure 5-10. It is a set of commands that also doubles as a display of the visibility status of each of the OATS windows. There is some overlap in function with the commands discussed in Section 5.4.1. Note that each of the OATS windows is listed in the menu in Figure

5-10. Clicking on a window's name in the menu makes that window become visible and places it in the front and active position. If the window is already visible, it is moved to the front and becomes the active window. A marker is placed in front of each window's name to indicate its status. The "-" minus sign indicates that a window is hidden. A null " " indicates that the window is visible. The check mark "✓" shows that the indicated window is the active window. Whenever the Graphics Window is empty, the generic name "Graphics Window" appears in the menu display. If plotting has been done, the menu shows the title of the plot layer that is on top.

5.4.3 WINDOW CONFIGURATION COMMANDS

These are the middle set of commands in Figure 5-10. They provide a wealth of additional commands in sub-menus that can be used to configure the three OATS windows and to manipulate selected aspects of the data in those windows where it is necessary.

5.4.3.1 Graphics Options

Figure 5-11 shows the menu options that can be expected from the selection of the **Graphics Options**. Most of these commands will be inactive if the Graphics Window is unopened or inactive.

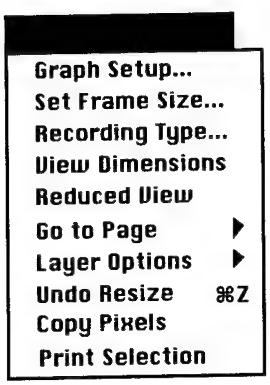


Figure 5-11. **Graphics Options** Sub-Menu

Graph Setup...

This command brings up the dialog shown in Figure 5-12, and allows the user to define the Graphics Window. This setup dialog is one of the first ones that a user should become familiar with when starting to work with OATS. It should be used to set the Graphics Window to a size appropriate to his needs, to his monitor, and to the power of his computer. The user will find that a large screen is easier to work with and provides a better view, but it also implies more pixels to process and plot and a consequently slower response time.

The DynaFace environment provides the capability to make plots onto a grid of n-by-m pages, as reflected by the *Page Number & Size* fields in this dialog. Each page will be of uniform *width* and *height*, as set by the user. The *Page Setup* controls can be used to quickly set the page sizes to the maximums allowed for a printed page; however, it should be noted that a non-square plot frame will produce scale distortions. The typical user will find that a 1-by-1 page size works best for most OATS processes. Larger page groupings are seldom necessary. Multi-page displays can also confuse new users regarding where a plot is being generated; however, the *Across* and *Down* settings can be set to plot multiple displays side-by-side and in the same saved picture. The *Reduced View* window shows the full-available plot area, and is used to keep track of where the visible Graphics Window is currently viewing. Controls exist to turn this option on or off and to change the view ratio between the reduced and full views. Once the Figure 5-12 Setup Dialog has been exited, the drawing area can be opened to its full size by clicking and dragging the size box located at the bottom right of the Graphics Window.

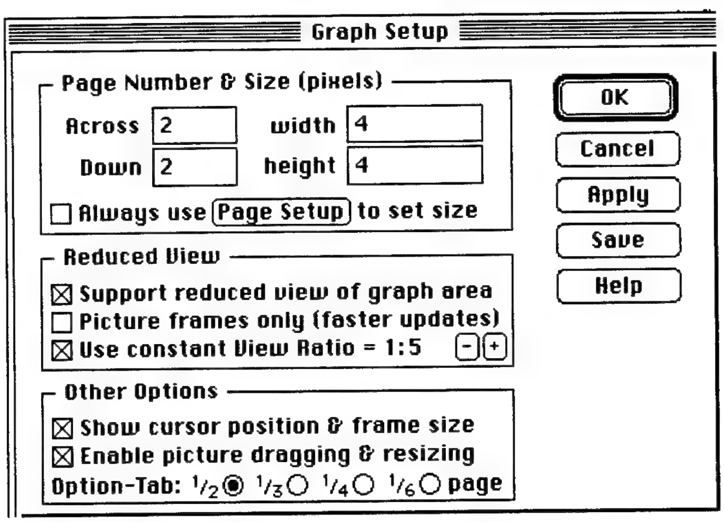


Figure 5-12. Graphics Window Set-Up Dialog

The *Other Options* checkboxes at the bottom of the dialog provide control over miscellaneous options possible with the Graphics Window. If the first checkbox is activated, the cursor position and frame size are temporarily displayed in the window title bar whenever the mouse is pressed. The ability to drag and resize pictures can be enabled/disabled. The last option specifies the size of a tab jump. The **TAB** key and **Shift-TAB** keys move the visible Graphics Window from page to page in a forward and backward direction. The **Option-TAB** and **Option-Shift-TAB** moves the plot frame by partial *page* increments, as indicated in Figure 5-12.

Set Frame Size...

The dialog shown in Figure 5-13 is displayed after this menu selection. This dialog presents an alternative to selecting the drawing frame area by using the click-and-drag method (See Section 4.4.1), which requires the user to "eyeball" the appropriate size for the frame settings. **Set Frame Size** allows the user to select the exact pixel settings for the *Top*, *Left*, *Bottom*, and *Right* sides of the frame. These settings will work in a multi-page environment. The *View* button will provide an update of the *Length* and *Width* according to your current settings. Upon an *OK* exit from this dialog, the plot frame will be present as per your settings.

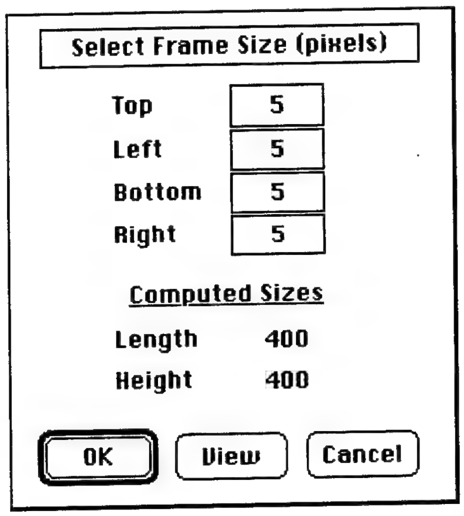


Figure 5-13. Dialog for Specification of Frame Size

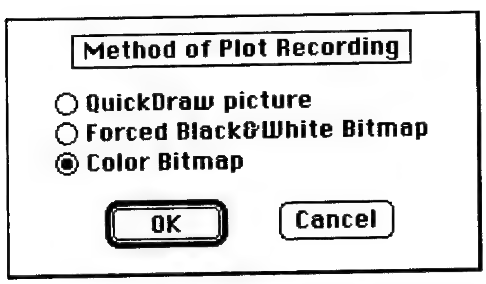


Figure 5-14. Dialog for Selection of Data Recording Method

Recording Type...

The dialog shown in Figure 5-14 is displayed and allows the user to select the manner in which plotted data is composed and recorded. An OATS *Bitmap* is composed of a grid of pixels with assigned values of black/white or of color. An OATS *Picture* is composed by a collection of QuickDraw (Reference 6) routines that produce basic geometrical shapes like lines, ovals, and rectangles. Although Color Bitmap recording is by far the method most often selected by OATS users, the specific choice depends on the intended use of the plots and the Graphics Window.

Picture drawings can be edited by MacDraw-like graphics editors, can be decomposed into component parts, and can be used to transfer QuickDraw pictures into and out of OATS. However, *Bitmap* plots are faster, require less memory for almost all normal OATS applications, and are employed for essentially all new OATS drawings. OATS plots can be composed of combinations of drawing layers done with a mixture of *Picture* and *Bitmap* settings; however, there is seldom any motivation to do so.

View Dimensions

This command brings up the informational dialog shown in Figure 5-15. Regardless of which window is currently active, it provides a summary of the settings in place for three sets of measurements for the Graphics Window. *Plot* information shows the dimensions of the active plot frame, *Total* information shows dimensions for the maximal plotting area, and *Visible* information shows dimensions of the visible on-screen Graphics Window. Horizontal and vertical sizes in pixels and in inches are shown. The screen resolution in pixels/inch is also provided, even though this is constant at 72 pixels/inch for most Macintosh computers. The center of the dialog shows a small pseudo-window with the *Top*, *Left*, *Bottom*, and *Right* values of the frame boundaries.

Reduced View / Full View

The menu selection toggles back and forth between these two menu options. Reduced View or Full View is shown as the desired option to implement. It is the opposite of that which is currently showing.

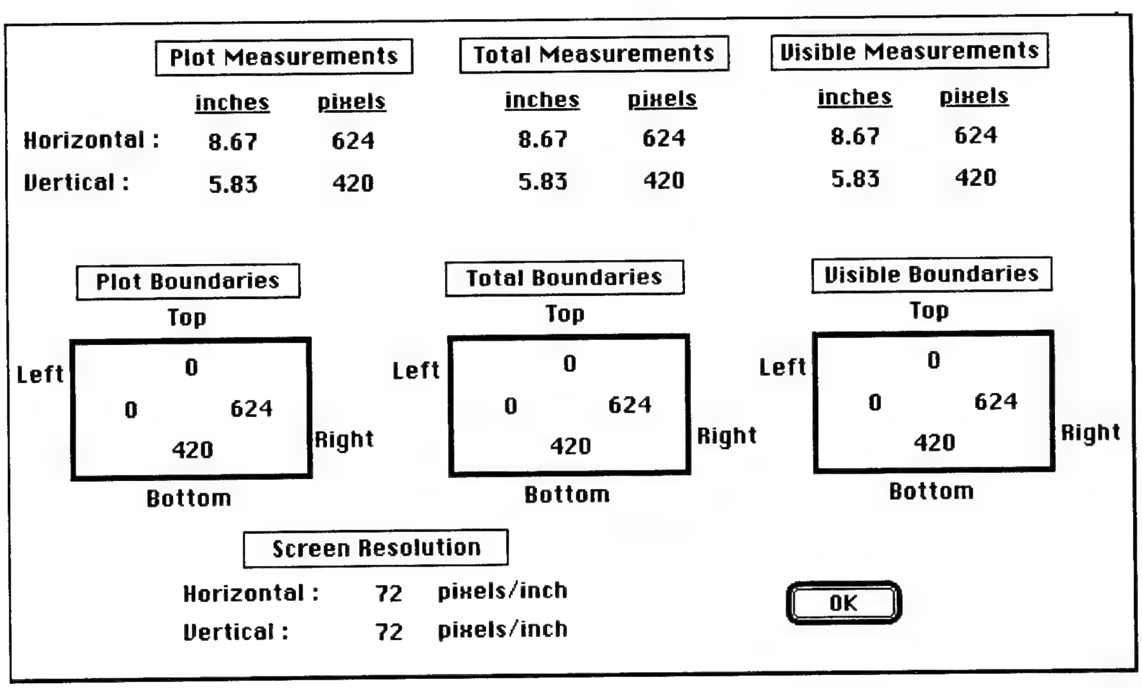


Figure 5-15. Graphics Window Summary Display

Go to Page

If the Graphics Window has been established with a multi-page environment, this menu selection provides a list of pages (1, 2, 3, ... N) which can be chosen. The Graphics Window is then automatically set to that page for graphing functions. If the plot environment is a single page, then this option is inactive.

Layer Options

This command presents a list of sub-sub-menus as shown in Figure 5-16. It provides a series of actions that can be applied to layers drawn in the Graphics Window.

Layer Options
- Bring To Front
- Send To Back
- Combine

Figure 5-16. **Layer Options** Sub-Menu

Bring to Front

The **Bring to Front** command is used to bring the selected layer of graphics to the top layer. This command only becomes activated (non-grayed) in the menu if more than one layer exists and a layer other than the top layer has been selected.

Send to Back

This command allows the user to send the top layer of the graphics window to the bottom layer. A new top layer can be activated by clicking on it in the Graphics Window. This command is also active only if more than one layer exists.

Combine

The **Combine** function is active only after the user has drawn at least 2 layers in the Graphics Window and has executed the **Select All** command or selected layers in the Graphics Tools window. It is used to group several layers of pictures into a single picture, often prior to a **Save** command.

Undo Resize

This command is used to restore a graphic to its original size after manually resizing the picture (see Section 5.5). This is also initiated with the **⌘-Z** command-key.

Copy Pixels

This command copies into the clipboard the selected portion of the total plot area highlighted within the plot frame. It provides the option of manipulating less than the sum total of the visible picture for pasting into another application or for moving it to another portion of the total plot area.

Print Selection

In a multi-page environment and after a portion of the total print area has been selected to be printed (e.g. one of the pages), this command can be used to select where the selected portion of the plot will be printed on the output page.

5.4.3.2 Normal Text Options

Figure 5-17 shows the menu options that can be expected from the selection of the Normal Text Options. Most of these commands will be inactive if the Normal Text tabular window is unopened or inactive.

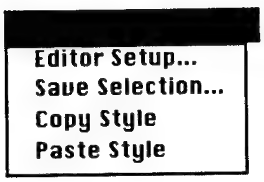


Figure 5-17. **Normal Text Options** Sub-Menu

Editor Setup...

This command brings up the dialog shown in Figure 5-18, and allows the user to define selected characteristics of the editor window. OATS uses editor windows primarily for text viewing rather than as formal editors, so this dialog is of modest importance; however, it does allow the user to specify the following window characteristics:

- Options on how the editor interprets the **ENTER** and **RETURN** keys.
- Options for the print set-up, including line height, margin indentations, and a format for page headers. Line height is also important for on-screen viewing, especially if a large-size font is used.
- Miscellaneous options such as activation of display of cursor position and selection size, page break and invisible character display, and indentations.
- The *Help* button sets no characteristics, but does produce a dialog with additional information on what these options mean.

The **Editor Setup** is probably most important in cases where the user wishes to make manual annotations to output listings which already exist in the Tabular Window prior to saving them to an output file.

Save Selection...

This command allows the user to save only a selected subset of the information displayed in the Normal Text Window. It brings up the standard Macintosh file interface, which allows the user to pick a directory and file name for the new file.

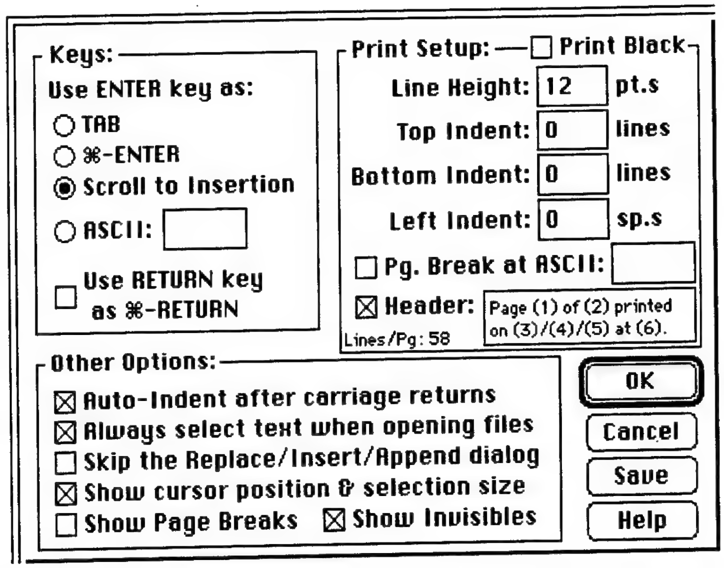


Figure 5-18. Editor Set-Up Dialog for Normal Text Tabular Window

Copy Style

Because the normal text editor is a full function editor, each subset of the text displayed can be assigned characteristics of font, size, style, and color. This **Copy Style** command can be used to copy the text settings from a highlighted text string. The text itself is not copied.

Paste Style

Designed to work in tandem with the **Copy Style** command, this menu selection allows the user to copy a text style onto a highlighted text string.

5.4.3.3 Volume Text Options

Figure 5-19 shows the menu options that can be expected from the selection of the Volume Text Options. Most of these commands will be inactive if the Volume Text tabular window is unopened or inactive.

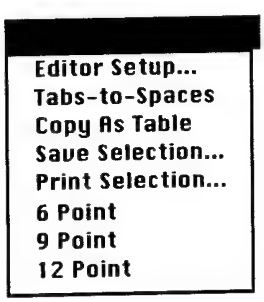


Figure 5-19. **Volume Text Options** Sub-Menu

Editor Setup...

This command brings up the dialog shown in Figure 5-20. Although very similar to the dialog for the Normal Tabular Window, there are some subtle differences--mostly in formatting. The user does have the option of having the window show a small tick mark at the top to mark column location.

Tabs-to-Spaces

The **Tabs-to-Spaces** command replaces all of the Tabs in the active text window with spaces. The original spacing is kept the same, except that there are no longer Tabs in the text.

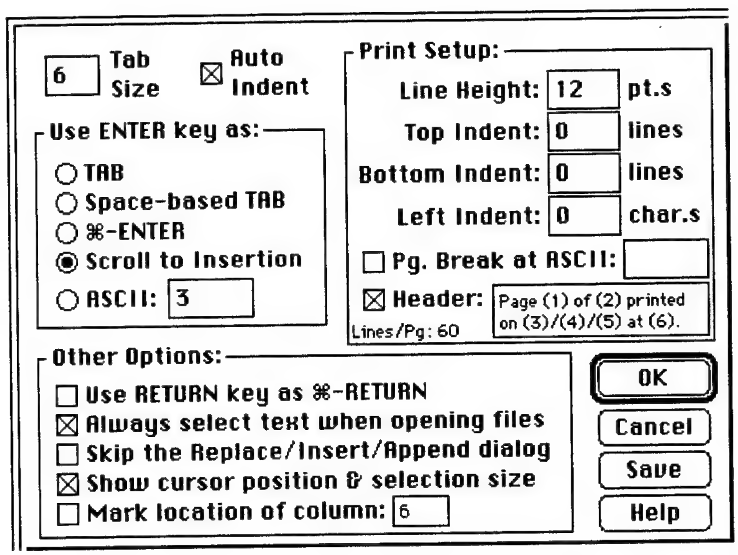


Figure 5-20. Editor Set-Up Dialog for Volume Text Tabular Window

Copy As Table

This command allows the user to select a portion of a text window and copy it to the clipboard. Each entry that is separated by one or more spaces is separated by a **TAB**. This formatting allows the data to be pasted directly into spreadsheet application software or onto another part of the text window in column format.

Print Selection...

This command allows the user to print only a selected subset of the information displayed in the Normal Text Window.

Save Selection...

This command allows the user to save only a selected subset of the information displayed in the Normal Text Window. It brings up the standard Macintosh file interface, which allows the user to pick a directory and file name for the new file.

6 point // 9 point // 12 point

The text in the Volume Text Window can be viewed as a 6, 9, or 12 point font; however, these choices apply to the entire window. These font size choices can be selected by highlighting the desired value with the mouse. The current value is shown with a check in front of it in the menu. The setting is maintained between executions of OATS only if a *Save* of settings is done in the Set-Up dialog.

5.5 NON-MENU PROCEDURES AND COMMANDS

Several environment-controlling procedures and commands are available that are not specifically called out in the menus.

- Reduced/Full Switching - Although the menus allow the user to switch back and forth between the Full and Reduced views in the Graphics Window, the **RETURN** and **ENTER** keys can also be used to switch back and forth with ease if the Graphics Window is active.
- Deselecting Plots - A simple click in the Graphics Window outside the plot frame will deselect all plotted items and set the plot frame equal to the entire window.
- Square Plot Frames - When manually defining a plot frame area, it is possible to force the area to be square by having the **CAPS LOCK** key pressed.
- Resizing Plots - To manually resize a plot or one drawing on a plot, move the cursor to the edge of the drawing and the cursor will turn into an arrow. Click-drag the edge of the drawing to the desired size This may be accomplished by extending one edge at a time, or by click-dragging on a corner of the drawing area to expand height and width simultaneously. Alternatively, a drawing can be resized by placing the mouse at the extreme point where the plot frame is to be expanded to, holding the **SHIFT** key, and clicking the mouse.

SECTION 6 - PROPAGATE MENU

The OATS program combines orbit propagation models with numerical and graphical coverage analysis algorithms. The design philosophy of OATS has been to separate the orbit models from the analysis processes. The primary reason for selecting this architecture is so that an arbitrary number of different orbit propagation models can be added to the program without affecting any of the analysis code; however, this architecture also makes it possible to perform analysis on an imported ephemeris generated by an external program that might use a propagator not available through OATS. Thus, as previously noted, the user must always have satellite ephemerides available before proceeding with any of the OATS coverage analysis functions. Although it is expected that a typical user will employ the OATS **Propagate** menu to generate ephemerides prior to performing analysis, imported ephemeris files can be used if they follow a prescribed format (see Section 10.2). The only difference apparent to the user between internally generated ephemeris files and imported ones is that processing will be slightly faster for the internally generated files.

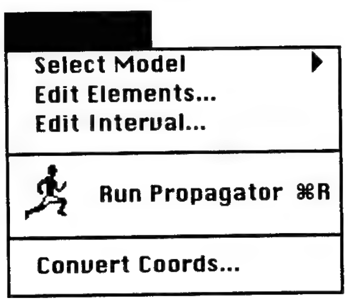


Figure 6-1. **Propagate** Menu

The **Propagate** menu is shown in Figure 6-1. It is an OATS analysis tool used to generate ephemeris files using one of a variety of orbit propagation models. The **Select Model**, **Edit Elements** , and **Edit Interval** menu selections are employed to set-up a computer run that will generate an ephemeris file. Their functions include access and display of orbital element sets. Once set-up is completed, **Run Propagator** is used to create the ephemeris file that can be used for graphical or numerical coverage analysis. This menu tree also provides a secondary capability via the **Convert Coords** option to transform from one type of orbital element set to another.

6.1 ORBIT PROPAGATION MODELS

Satellite ephemerides can be computed by any one of four orbit propagators provided with OATS version 5. The abbreviations for each of these models is the same as those used in the OATS menu system. The format for the orbital elements for each propagator is provided in Section 10.1.

- **PPT2** - This propagator uses a full Brouwer-Lyddane analytic model for propagation and requires the input of a One Line Element Set (OLES). Three different OLES formats are available, including:

  PME

  Charlie

  Z (also designated Zulu)

- **RUK12** - This is a fourth order Runge-Kutta numerical integration with a WGS84 geopotential of order and degree 12. The input for this model is an osculating Cartesian state vector and an epoch for the state vector. This model requires a small integration step size to obtain accurate results (typical values range from 1 to 10 seconds). This step size is rather small for plotting and coverage analysis and tends to yield very large ephemeris files to store the data. Because of this, the user specifies the integration step size for the propagation as well as an output interval for the ephemeris data.
- **J2** - The J2 propagator uses a first order analytic theory with earth oblateness effects. The input elements are mean Keplerian orbital elements and an epoch for these elements.
- **SGP4** - This is used to propagate Two Line Element Sets (TLES) generated by USSPACECOM (formerly NORAD). The model is used for near-Earth satellites, defined by USSPACECOM as having periods under 225 minutes. The SGP4 model (Reference 7) was developed by Ken Cranford in 1970. It is a simplification of the extensive Lane and Cranford analytical theory, which uses Brouwer's solution for its gravitational model and a power series density function for its atmospheric model.

6.2 PROPAGATION COORDINATE SYSTEMS

Two coordinate systems are referred to through the remainder of this section. They are Earth Centered Inertial (ECI), and Earth Centered Fixed (ECF). The fundamental plane of the ECI system is the mean Celestial Equator. The x-axis lies in the direction of the Vernal Equinox and the z-axis points toward the North Celestial Pole. The ECF system is a non-inertial, rotating system which is fixed to the earth. The fundamental plane of the ECF system coincides with that of the ECI system. The x-axis is rotated about the Celestial Pole through the Greenwich hour angle. The effects of precession and nutation of the Earth pole are ignored. All of the analysis and plotting functions in OATS to which satellite ephemerides are input require the coordinate frame to be ECF. The output coordinate system for all of the OATS propagation options is ECF.

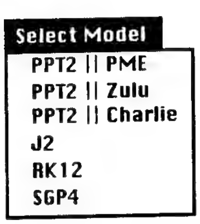


Figure 6-2. **Select Model** Menu

6.3 <u>HOW TO GENERATE AN EPHEMERIS FILE</u>

6.3.1 PROPAGATOR MODEL SELECTION

To set up an ephemeris generation run, choose the **Select Model** option from the menu shown in Figure 6-1. This will produce the sub-menu shown in Figure 6-2, which allows the user to select one of the six possible combinations of orbit propagator plus orbit element format described in Section 6.1. Choice of one of the six options will bring up individual dialogs that allow the user to enter specific orbital element data.

6.3.2 ORBITAL ELEMENT DATA ENTRY

Orbital elements are entered via one of the dialogs shown in Figure 6-3 through Figure 6-8. These dialogs are used all places throughout OATS where it is necessary to view the orbital elements. In their native format, some of the orbital element formats are condensed (see Section 10.1) and it is awkward to visually interpret the component parts. Through this set of dialogs, OATS provides the service of a user friendly display of the orbital elements for each of the propagation models. Note that OATS maintains a single storage location for each of the four types of orbit element propagators. Hence, if at first a set of J2 elements is being manipulated and the user changes to RUK12 for a while and then returns to J2, the J2 data will be maintained. These six dialogs are very similar in many respects, and are discussed as a group. Explanation of the orbital element components is provided in Appendix C.

The various input fields for all six dialogs are all individually labeled, and should be generally self-evident if the user understands the discussion presented in Appendix C. All input fields are labeled with appropriate units, if any, and the user is advised to strictly adhere to them. In addition to their input fields, the J2 and RUK12 input dialogs also have a set of radio buttons to choose whether the reference frame is ECI or ECF. The J2 dialog has an additional set of radio buttons to choose if mean or true anomaly is employed in the orbital elements. Note that the orbit epoch *Year* is entered as a 4-digit integer for the J2 and RUK12 cases, as a 2-digit year spanning the range from 1951 through 2050 for the SGP4, PPT2-Charlie, and PPT2-Z cases, and a 1-digit year for the PPT2-PME case. This very narrow range for the PPT2-PME case has necessitated the addition of a special button in the dialog shown in Figure 6-3. The *YR Help* button will bring up the dialog shown in Figure 6-9 that allows the user to unambiguously select any 4-digit year as the start year for the 10-year span of validity. The RUK12 orbit propagator carries a place to input the *Integration Time Step*, which is the interval used by the orbit propagator to perform computations. This interval should not be confused with the ephemeris interval (see Section 6.3.3) which is the time step

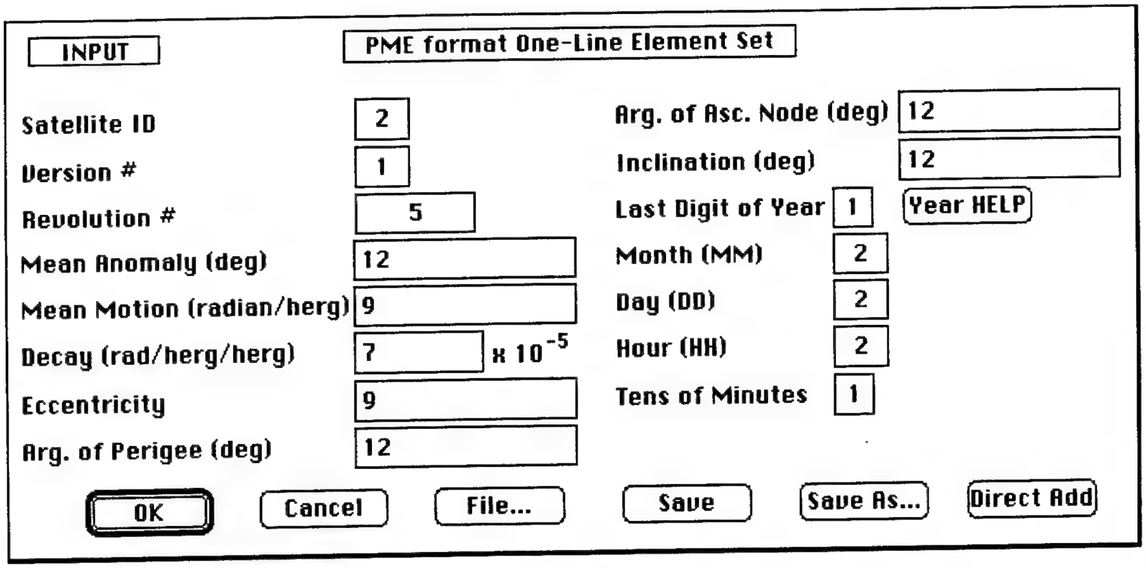


Figure 6-3. Dialog of Orbital Elements for PME Format One Line Element Set

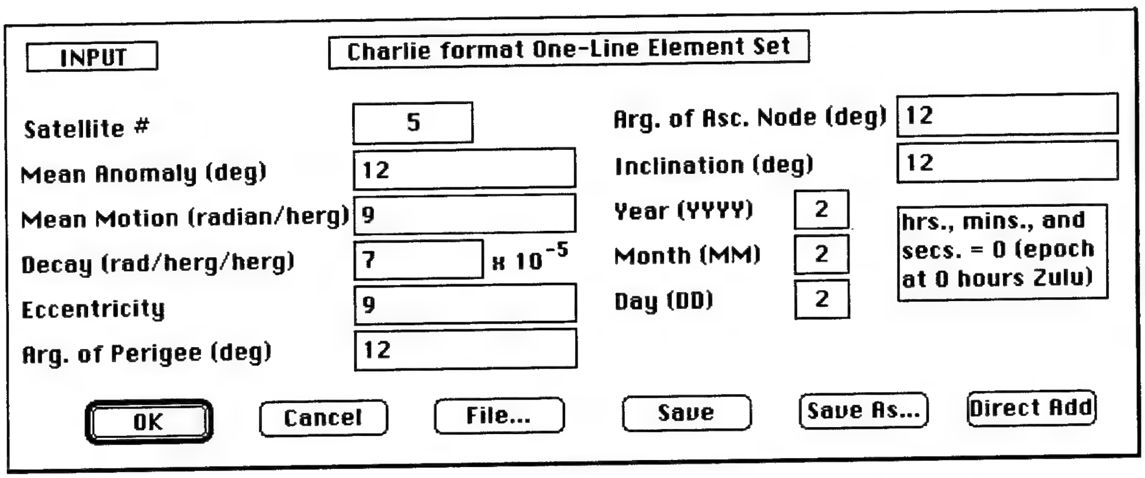


Figure 6-4. Dialog of Orbital Elements for Charlie-Format One Line Element Set

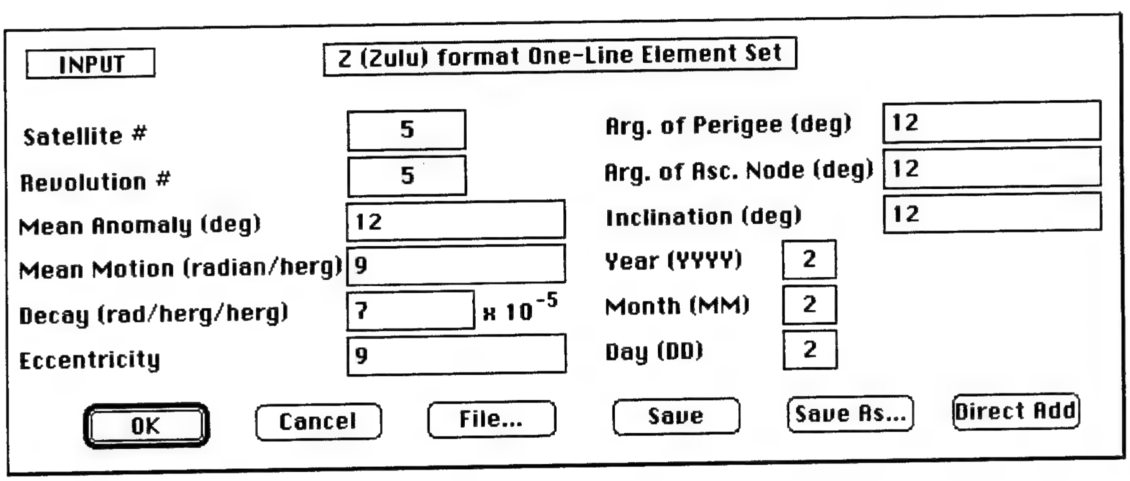


Figure 6-5. Dialog of Orbital Elements for Z-Format One Line Element Set

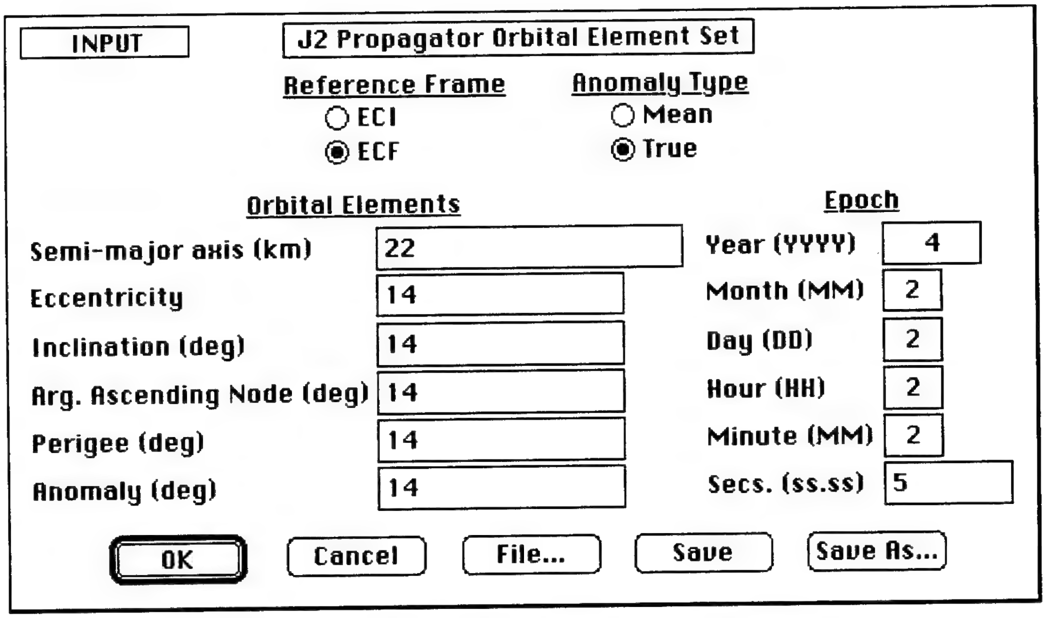


Figure 6-6. Dialog of Orbital Elements for J2 Propagator

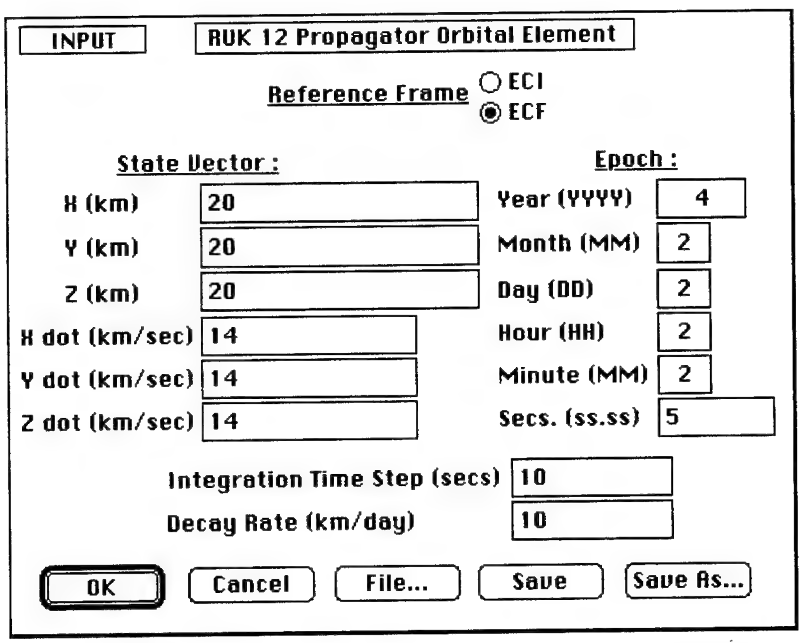


Figure 6-7. Dialog of Orbital Elements for Runge-Kutta Propagator

used to output ephemeris computations. The *Integration Time Step* should be smaller than or equal to the ephemeris interval. The RUK12 orbit propagator also has a place to input the *Decay Rate*, where the decay rate in km/day specifies a uniform decrease in the mean orbital altitude.

Each of the orbit element dialogs in Figures 6-3 through 6-8 also provides five identical main option buttons. The *File* button brings up a standard Macintosh interface dialog which allows the user to locate an

existing input file of orbital elements in any directory. *Cancel* or *OK* from this standard interface dialog will both return the user to the orbital elements dialog. OATS performs only basic file I/O checks at this point, returning an alert if the file cannot be opened or if a read error occurs. *OK* from the standard interface dialog will immediately read the file of orbital elements and display the retrieved values, even if they are not valid.

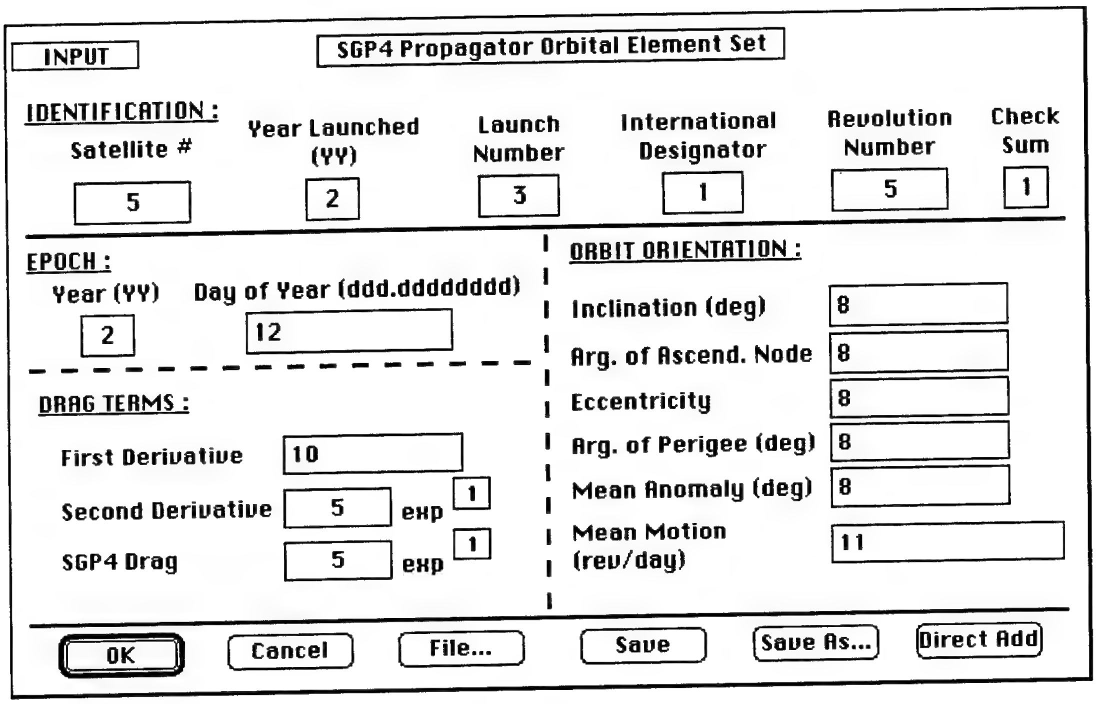


Figure 6-8. Dialog of Orbital Elements for SGP4 Two Line Element Set

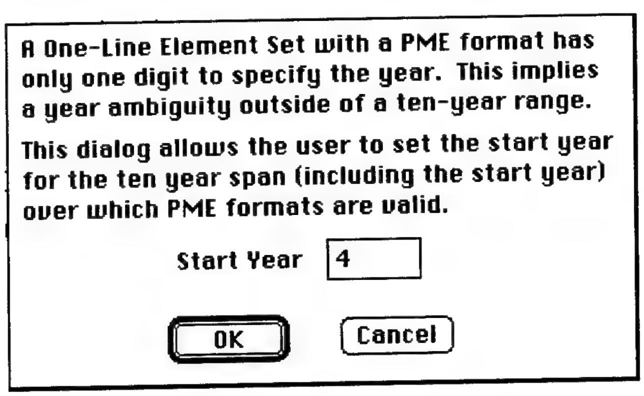


Figure 6-9. Dialog for Specification of Year Interval for PME-Format One Line Element Set

The *Save As* button in the orbit element dialogs brings up a standard Macintosh interface dialog which allows the user to specify the name for an existing output file of orbital elements in any directory. *Save* will overwrite a previously saved file of orbital elements, but will ask permission first (see Section 6.5). If a previous save has not occurred, *Save* behaves like the *Save As* option.

The *Cancel* button in Figures 6-3 through 6-8 returns the user to the main menu with no changes made to the orbital elements seen when the dialog was opened. *OK* will perform checks on the data as entered before exiting the dialog and issue an alert if a problem is detected; however, the checks are limited. **The user is cautioned that he is ultimately responsible for the validity of entered data.**

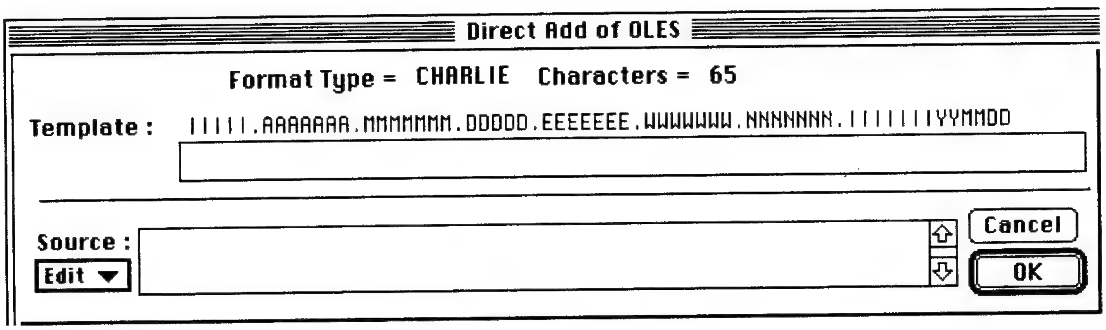


Figure 6-10. Dialog for Direct Entry of One Line Element Set

The OLES and TLES orbital element sets exist in a condensed form in their native format (see Section 10.1). The dialogs for these orbital element sets, Figures 6-3 to 6-5 and Figure 6-8, have an additional button called *Direct Add*. Although it is faster to enter orbital elements via a file prepared prior to running OATS or by entering them directly into the separate fields in the dialogs, this is not always the most convenient option. The *Direct Add* feature is available for those cases where the user wishes to enter an OLES or TLES directly and verbatim into OATS. Punching this button on an OLES dialog will bring up a dialog like that seen in Figure 6-10. The format type, number of characters, and data template supply information about the OLES, and are adjusted according to the type of OLES expected. The user has three options, the simplest of which is to type in the required data below the *Template*. The second alternative is to use the pull down menu under *Edit* to open simple text files into the mini-editor window shown in Figure 6-10. The window is small because an OLES is small and because there is no capability to do word-processing in this portion of the program. Sufficient capability is provided only to locate and copy an OLES, and then to paste it from the external source into the area provided for an OLES direct add. The *Edit* menu options are shown in Figure 6-11. The last alternative is to use the clipboard to copy and paste an OLES into the template area. This is not as convenient as using the mini-editor because it entails temporarily exiting OATS; however, it is necessary for some non-simple text sources. When the *OK* is pressed in the Figure 6-10 dialog, OATS will read the entered line, return to the dialog, and display the data appropriately in the separate dialog fields. If an entry error is detected, OATS will issue an alert and return to the orbital element dialog. For a TLES the dialog shown in Figure 6-12 appears when *Direct Add* is pushed. A similar data entry procedure is followed, except that two lines of user input will be required and two copy/paste operations may be involved.

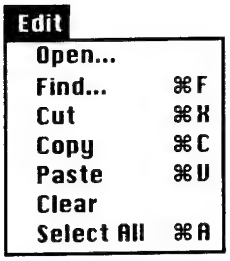


Figure 6-11. Direct Add Pull-Down Menu

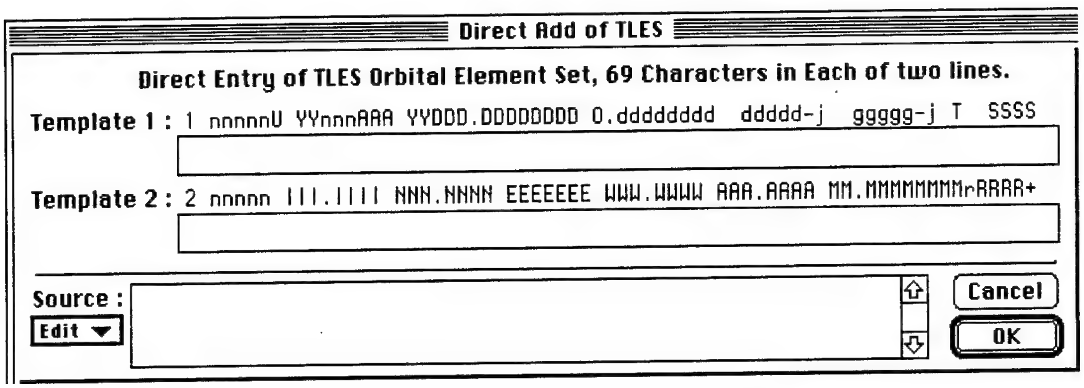


Figure 6-12. Dialog for Direct Entry of Two Line Element Set

Because the orbital elements dialogs shown in Figures 6-3 through 6-8 are used in multiple places, a flag field appears in the upper left corner of each dialog. This flag field has the values:

- INPUT - orbital elements are being used as program input
- OUTPUT - orbital elements have been produced as computed values
- VIEW - orbital elements are presented for inspection only and cannot be altered

For generating an orbit ephemeris, the flag field should read INPUT.

6.3.3 INTERVAL SELECTION

When the user passes through the **Select Model** menu option and subsequently exits any of the orbit element entry dialogs with an *OK*, the *Set Ephemeris Interval* dialog shown in Figure 6-13 is automatically displayed. The primary function of this dialog is to set the interval of the generated ephemeris file. The *Specify by* radio buttons permit choosing the interval via inputs of *Start Time* and *Stop Time* or by *Start Time* and a user selected *Number of Revolutions*. As shown above, all orbit elements have an epoch date, at which time the elements are valid. This date is entered in the preceding elements dialog, and is displayed as the default *Start Time* in Figure 6-13; however, it can be manually changed. The *Step Size* in seconds is the interval between computed ephemeris records.

If the interval is specified by the number of revolutions rather than being manually entered, the user may verify that the interval is acceptable by punching the *SHOW Conversion* button. The *Stop Time* will be computed using Kepler's equation and displayed. It is not required to make this check--the user may exit with an *OK* and the *Stop Time* will be internally computed. Note that if a new *Number of Revolutions* is selected after computing a *Stop Time*, the computed time is not used. Negative values of revolutions are unacceptable, as is a manually entered *Stop Time* that implies an orbit propagated backwards in time. Exiting the dialog in Figure 6-13 with either the *OK* or the *Cancel* will return the user to the main menu.

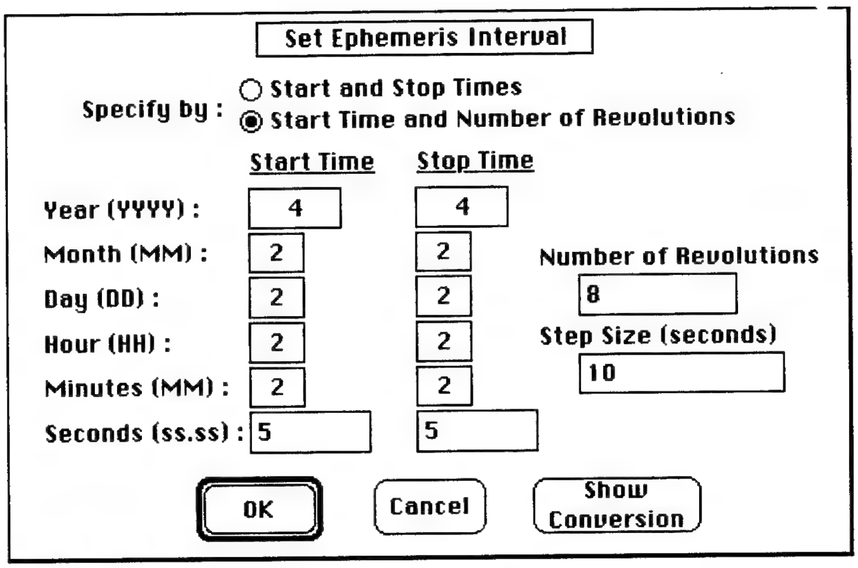


Figure 6-13. Dialog Used to Set Ephemeris Interval

6.3.4 SET UP CORRECTIONS

Before initiating the ephemeris file generation, the user may modify the orbital elements and/or the ephemeris interval by using the **Edit Interval** and **Edit Elements** menu options from Figure 6-1. Editing the orbital elements by way of the **Edit Elements** menu will not automatically bring up the interval dialog. If the user wishes to change the model for the orbit propagator, it is necessary to start over with **Select Model**. Similarly, these two menu options are not valid choices if a propagator model has not been selected. An alert will be issued.

6.3.5 GENERATING THE EPHEMERIS FILE

After all data have been entered, the ephemeris file generation is initiated with the **Run Propagator** command from the **Propagate** menu in Figure 6-1. Alternatively, the **⌘-R** command key may be used. After initiation, the user will be presented with the Macintosh standard file interface so that a name and

location for the ephemeris file can be selected. Exiting this dialog with an *OK* will create an ephemeris file in the ECF coordinate system. If the user has elected to have a progress display (see **System Params** under Section 5.1), a graphic will be presented as discussed in Section 6.5. If dictated by a flag set in **System Params**, a tabular window will be opened and a simultaneous printout of the ephemeris data will be displayed as it is generated. After a new ephemeris file is generated by OATS using the procedures described here, the file is automatically added to the list of active ephemeris files. The significance of this is explained in Section 9.1.

6.4 COORDINATE CONVERSIONS

A limited set of orbit element coordinate conversions is made available through OATS. The possible conversions can be seen graphically in Figure 6-14, the dialog that is presented to the user after selecting the **Convert Coords** option from the **Propagate** menu. The user should note that no orbit element coordinate conversion is going to be exact. For proper and precise propagation of an orbit, the orbit element set must be matched to the propagator model for which the elements were computed. However, these coordinate conversions do serve several useful purposes:

- They will provide a more intuitive look at an orbit specified by an OLES or TLES by presenting it in a Cartesian or Keplerian format.
- They make comparison of two differently specified orbits possible by providing a common format for orbit element display, even if the computed values are only very close approximations.
- They provide a basis for transforming an orbit element set so it can be used by another piece of software that cannot handle some of the orbit propagation models that OATS has available.

An orbit element coordinate conversion is performed by selecting one of the mutually exclusive set of *FROM* elements and one of the mutually exclusive sets of *TO* elements. *Cancel* will return the user to the main menu, and *OK* will bring up one of the orbit element dialogs in Figures 6-3 through 6-8. The flag field will be set to INPUT to show that the user is expected to input the orbital element set that will act as the source data to be converted. Data entry into these dialogs for coordinate conversions is handled just as was described in Section 6.3.2 for data entry to generate an ephemeris file.

When the INPUT coordinates are set, and an OK is clicked, the conversion will be performed as specified in the opening dialog (Figure 6-14) and the output will appear in a dialog like that shown in Figures 6-6 or 6-7. The flag field will show OUTPUT to indicate that the displayed data is a computed product. Orbit elements can be saved to an external file, which is a useful feature for saving the outcome of a comparison.

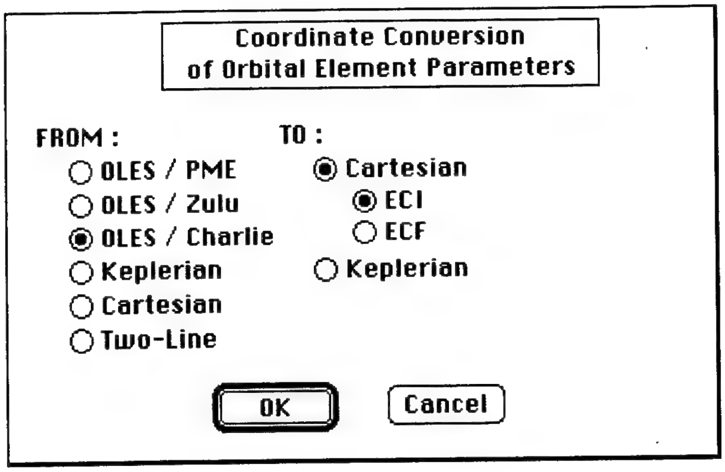


Figure 6-14. Dialog for Selection of Type of Orbital Element Coordinate Conversion

6.5 UTILITY DIALOGS

There are several utility dialogs used in the **Propagate** menu system. The first is shown in Figure 6-15, and is displayed when the user elects to overwrite an existing ephemeris file and the Macintosh standard interface protections do not apply. Ephemeris files are very important, and special care is taken to prevent the user from accidentally destroying one. Possible cases of file overwrite by OATS are flagged for the user with this dialog, which presents the *File* name and allows the user to proceed with the file overwrite with the *OK* button or to *Cancel* the operation and return to the main menu.

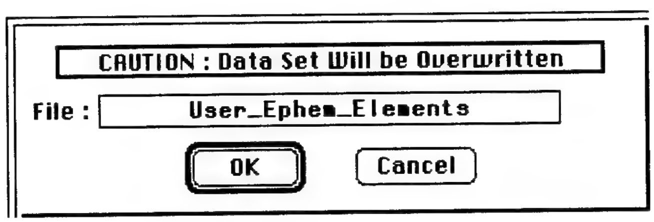


Figure 6-15. Ephemeris Data Set Protection Dialog

The second utility dialog appears while generating the ephemeris file, but only if selected for in the **System Params** dialog (see Section 5.1). This dialog displays progress toward completion of the generation of an ephemeris file. As seen in Figure 6-16, it shows the file name, a tabular value of percentage of file completed, and a fill-bar graphic showing progress toward completion. A chime will sound when the process is complete, making it possible to attend to other non-related matters until OATS is finished. This graphic can be valuable in cases where very large files have been selected or when a poor selection of generation parameters results in a file that is undesirably large. If the user suspects there is a problem, the file generation process can be stopped by clicking the *Stop* button in the fill-bar progress

graphic. An alert will be issued, processing will stop, and any portion of the generated ephemeris file will be deleted.

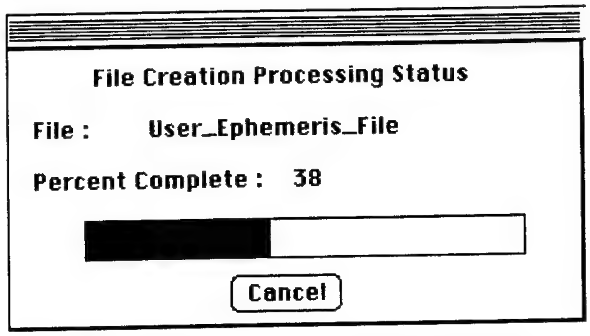


Figure 6-16. File Generation Progress Display

SECTION 7 - PLOT MENU

All of the OATS plot functions are defined and initiated through the **Plot** menu shown in Figure 7-1. Because graphical displays of satellite coverage and coverage related phenomena are the primary thrust for the development of OATS, this menu is quite important and has many options.

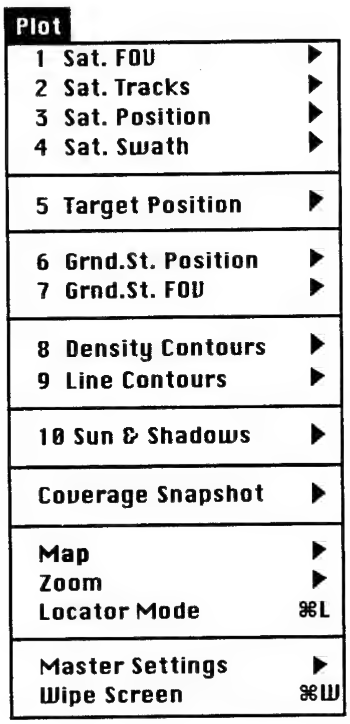


Figure 7-1. **Plot** Menu

The **Plot** menu is organized into four groups of commands. The first grouping is a set of ten commands that allow the user to directly plot satellite coverage or to plot structures like target positions or a satellite track that are related to coverage. These ten commands appear numbered in the **Plot** menu, and the numbering scheme is maintained wherever there is an OATS function related to plotting. Note that there is an intentional symmetry in the plotting menus and their associated commands. This leads to many similarities in the descriptions of the sub-menus and associated dialogs; however, the somewhat repetitious nature is required for those users that employ the manual to look up single commands rather than for cover-to-cover reading. The second grouping contains a single command for computation and manipulation of snapshots, defined as the instantaneous interaction of the fields-of-view of several spacecraft. The third grouping contains commands related to plotting and display of map data. The **Map** menu and its options are especially important to the operation of OATS. The final section contains a set of miscellaneous plotting commands that enhance the display or usefulness of the basic plot functions.

All plot activity initiated from the **Plot** menu will manifest itself in some way in the OATS Graphics Window. The user should note that it is not necessary for the Graphics Window to be visible or active for plotting to occur; however, it is generally advisable to have the Graphics Window active so that the user can see what is drawn as it appears on screen. Although it is preferred to show full titles for each of the **Plot** commands, space limitations dictate that some of the menu options are abbreviated. The convention will be to use the unabbreviated commands when presenting the menu selections.

The various commands in the **Plot** menu share many common features. Each of the ten basic commands begins with an **Options** selection that presents a dialog that allows the user to set parameters that define the graphic to be plotted. Each also finishes with a **Plot** selection that initiates the defined plot. These commands can also be initiated with a **⌘-n** command-key, where "n" is one of the ten numerical characters from "1" through "0" (the zero is tenth) corresponding to the sequence of the plot-structure command. Depending upon function, the plotting commands will also have **Icon Color**, **Line Color**, or **Shading Color** commands available, all of which will bring up the Color Selection utility dialog discussed in Section 7.17. In a similar fashion, **Line Definition** and **Shading Density** are commonly utilized menu options for **Plot** commands. For the sake of brevity, only those menu selections that initiate a unique response will be discussed in detail. Dialogs shared between several interfaces are discussed in Section 7.17.

7.1 SATELLITE FIELD-OF-VIEW

Figure 7-2 shows the menu selections available for **Satellite Field-of-View**. This series of plot commands is used to plot the FOV seen by a satellite antenna.

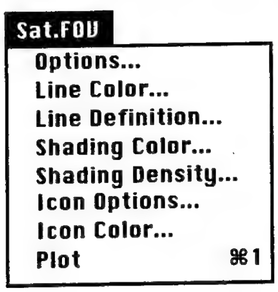


Figure 7-2. **Satellite Field-of-View** Menu

Options...

The dialog that appears from the **Options** command appears in Figure 7-3. This dialog is not available to the user unless at least one ephemeris file has been opened (see Section 9.1). A list of files in the active *Ephemeris File List* appears in the scroll list to the left of the dialog. The satellite FOV is plotted from whichever of these files is active. The first open file is the default

selection when this dialog is initially accessed, but a different ephemeris can be selected by clicking the mouse on the name of the new file in the list. Once selected, the identity of this active file is distributed to most of the **Plot** dialogs. To eliminate uncertainty, the name of the active file is displayed in the *Active File* area below the list. The *Time* at which the FOV will be plotted is displayed in the *Year, Month, Day, Hour, Minute,* and *Secs* fields to the upper right of the dialog. The time is defaulted to the beginning of the ephemeris file, but can be reset by the user to any time during the interval covered by the file. As an aid in selecting the *Time*, the *Time Span* is displayed and shows the limits covered by the current active file. The *Time* displayed in this dialog is linked to the time shown in the **Satellite Position** and **Sun & Shadows** menu items (see Figure 7-1). Settings available through the *SET ANTENNA Parameters* and *SET ATTITUDE Parameters* are discussed in Section 7.17. The *SET ATTITUDE Parameters* button is active only if the radio buttons in the center of the dialog indicate that *Use Attitude Data* is active. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all satellite FOV parameters as shown in the dialog.

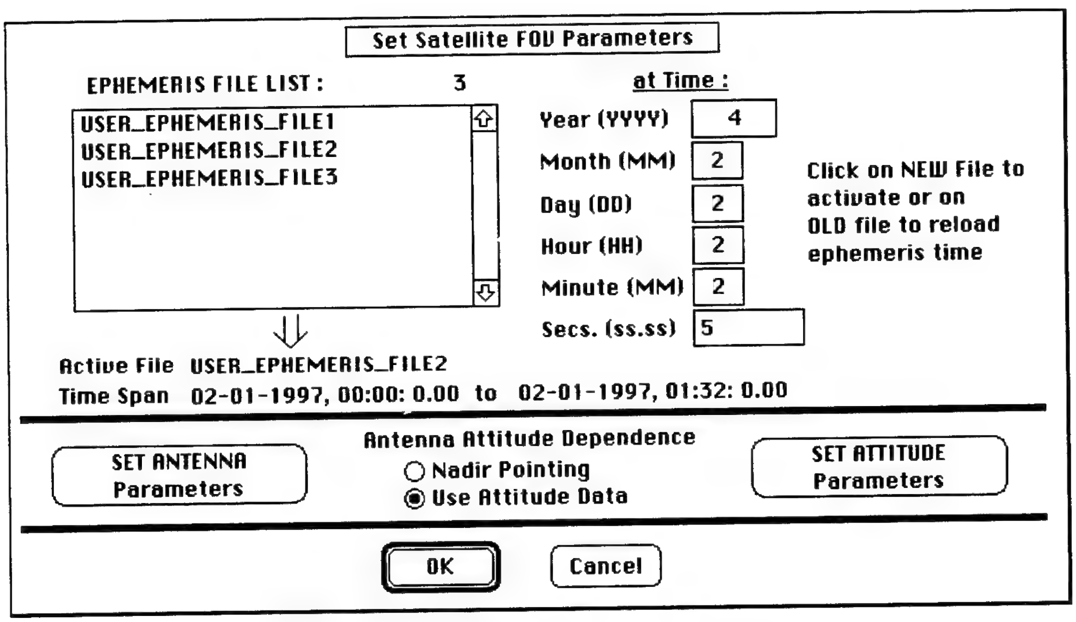


Figure 7-3. Satellite Field-of-View Dialog

Icon Options...

The small dialog seen in Figure 7-4 is brought up, allowing the user to select whether or not an icon is to be plotted at the boresight of the satellite antenna and how large it should be. The small icon picture at the top is merely a reminder of what the boresight plot icon looks like. While the boresight for a simple nadir-pointing satellite may be extraneous information, the boresight can be

useful in understanding the pointing and location for an antenna that has sufficient attitude amplitude that it does not intersect the surface of the Earth.

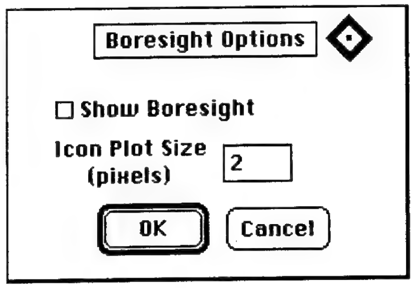


Figure 7-4. Satellite Field-of-View Icon Options Dialog

7.2 <u>SATELLITE TRACKS</u>

Figure 7-5 shows the menu selections available for **Satellite Tracks**. This series of plot commands is used to plot the line path traced by an Earth orbiting a satellite. Since some map projections are two-dimensional and some are three-dimensional (see Section 7.12), this menu and the interfaces it calls make provision for plotting the track of the satellite projected onto the surface of the Earth as well as a three-dimensional orbit path.

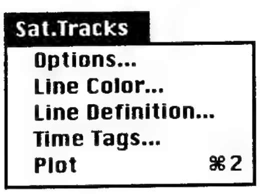


Figure 7-5. **Satellite Tracks** Menu

Options...

The dialog that is called by the **Options** command appears in Figure 7-6. This dialog is not available to the user unless at least one ephemeris file has been opened (see Section 9.1). A list of files in the active *Ephemeris File List* appears in the scroll list to the left of the dialog. By selecting a file, the user determines which satellite track will be plotted. The first open file is the default selection when this dialog is initially accessed, but a different ephemeris can be selected by clicking the mouse on the name of the new file in the list. Once selected, the identity of this active file is propagated throughout most of the **Plot** dialogs. To eliminate uncertainty, the name of the active file is displayed in the *Active File* area below the list. The *Start Time* and *Stop Time* are taken from the current active ephemeris file, but may be reset by the user so long as the times are within the confines of the time period covered by the file. The default values of *Start Time* and *Stop Time* are the endpoints of the current active ephemeris file. If the user needs to reinitialize

the times on the current active file, that file name can be clicked as if it were a re-selection of the ephemeris file. The times displayed in this dialog are linked to the times shown in the **Satellite Swath** menu (see Figure 7-1).

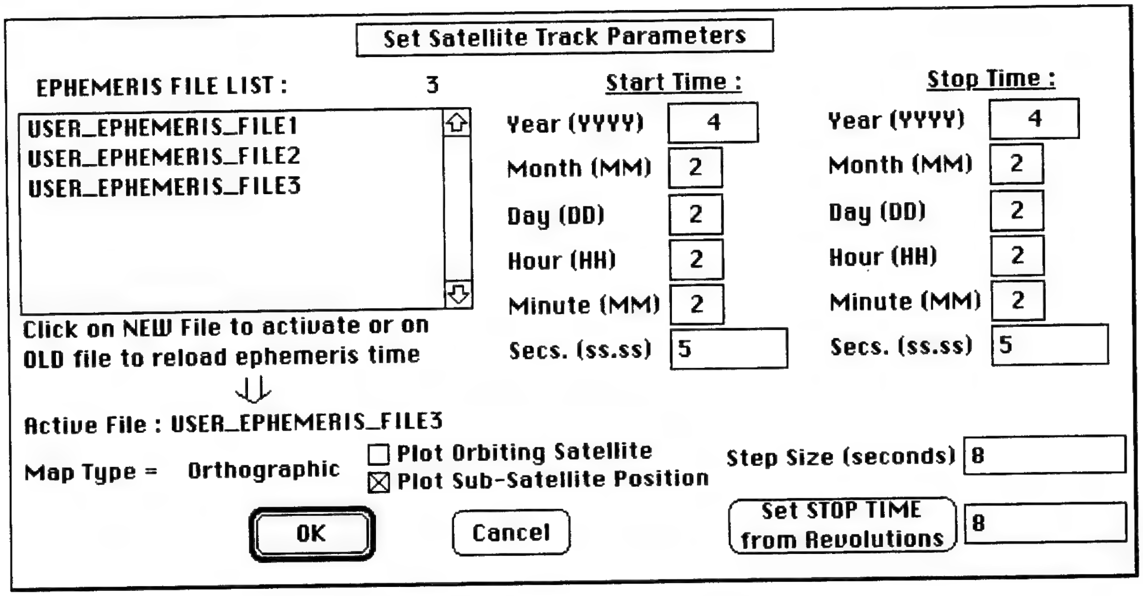


Figure 7-6. Satellite Tracks Dialog

OATS will identify the current *Map* projection (see Section 7.12), as it helps to explain the relevance of the selection of *Plot Orbiting Satellite* and/or *Plot Sub-Satellite Position*. The space track is a viable option only for three-dimensional plots, in which case at least one of the ground or space track options must be selected. The *Step Size* is the time interval in seconds between successively plotted points along the track. Since plotted tracks consist of a series of connected straight line segments, the smoothness of the plot is a function of step size. A smaller step size implies a smoother plot, but also implies a longer execution. *Step Size* is independent of the ephemeris step size interval. The *Stop Time* can also be set according to a user supplied number of *Revolutions*. This makes it easy, for example, to specify 3 orbits and have OATS compute the plot interval with the push of a button rather than estimating it and manually assigning a *Stop Time*. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all satellite track parameters as shown in the dialog.

Line Definition...

The **Line Definition** dialog seen in Figure 7-7 is similar to the one seen in Section 7.17; however, it is unique in this case because two possible line types can be set in the same dialog--the line for ground tracks and those for space tracks. A set of four radio buttons is available for each type to select plot track line thicknesses. A standard slide control is available to set the line density according to a range of 10 settings from solid through open and broken.

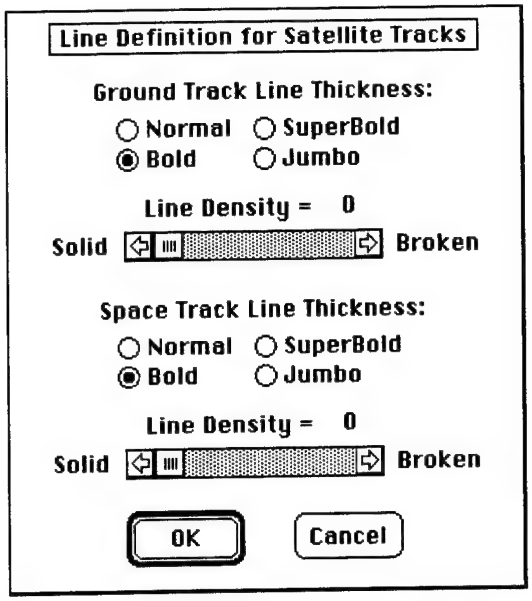


Figure 7-7. Satellite Tracks Line Definition Dialog

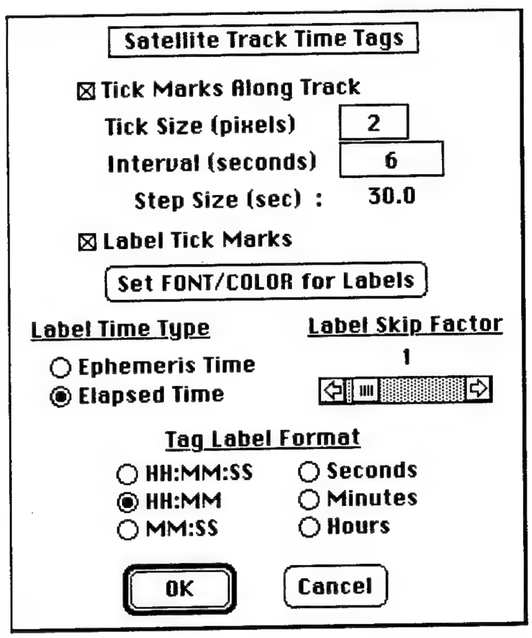


Figure 7-8. Satellite Tracks Time Tags Dialog

Time Tags...

In order to show the time dependence of a satellite track, OATS provides the capability to place labeled tick marks along the plotted track. These time tags are controlled via the dialog shown in Figure 7-8. *Tick Marks Along Track* to signify time points along the satellite tracks(s) may be flagged on or off. If on, the user may select the *Tick Size* in pixels as well as the *Interval* in seconds between ticks. Label Tick Marks can turn labeling of the ticks on or off, and the Set

FONT/COLOR button can be used to define the appearance of the labels (see Section 7.17). The time tags *Type* can be selected to coincide with an *Elapsed Time* from the start time of the plot or to the *Ephemeris Time* derived from the file used to generate the satellite track. The *Label Skip Factor* permits a variable number of ticks to be skipped between label attachments. Radio buttons allow the user to select from one of six *Label Formats* for the labeling of time tags. Integral values of *Seconds, Minutes*, or *Hours* may be chosen, as well as formatted combinations of hours (*HH*), minutes (*MM*), and seconds (*SS*). The user is cautioned to try to pick an Interval for time tags that is an even multiple of the *Step Size* used to plot the track (see Figure 7-6). OATS will attempt to adjust a poor selection; however, the algorithm is not foolproof.

7.3 SATELLITE POSITION

Figure 7-9 shows the menu selections available for **Satellite Position**. This plot command is used to plot a satellite icon at the geographic and/or space positions for a user-selected time based on whichever of the ephemeris files is active and depending on the map projection in use. Satellite icons are shown in Figure 7-10.

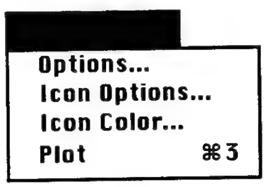


Figure 7-9. **Satellite Position** Menu

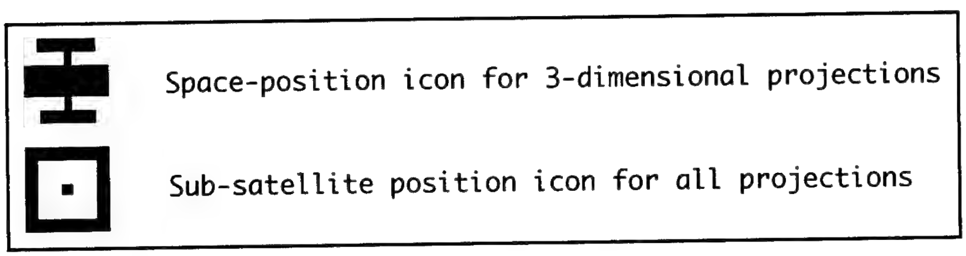


Figure 7-10. Satellite Position Icons

Options...

The dialog that is called by the **Options** command appears in Figure 7-11. It is not available to the user unless at least one ephemeris file has been opened (see Section 9.1). A list of files in the active *Ephemeris File List* appears in the scroll list to the left of the dialog. By selecting a file, the user determines which satellite track will be plotted. The first open file is the default selection when this dialog is initially accessed, but a different ephemeris can be selected by clicking the

mouse on the name of the new file in the list. Once selected, the identity of this active file is distributed to most of the **Plot** dialogs. To eliminate ambiguity, the name of the active file is displayed in the *Active File* area below the list. The *Time* from the ephemeris at which the position(s) will be plotted is displayed in the *Year, Month, Day, Hour, Minute,* and *Secs* fields to the upper right of the dialog. The time is defaulted to the beginning of the ephemeris file, but can be reset by the user to any time during the interval covered by the file. As an aid in resetting the *Time*, the *Time Span* is displayed and shows the limits covered by the current active file. The *Time* displayed in this dialog is linked to the time shown in the **Satellite Field-of-View** and **Sun & Shadows** menu items (see Figure 7-1). OATS will identify the current *Map* projection (see Section 7.12), as it helps to explain the relevance of the selection of *Plot Orbiting Satellite* and/or *Plot Sub-Satellite Position*. The space position is a viable option only for three-dimensional plots, in which case at least one of the ground or space position options must be selected. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all satellite position parameters as shown in the dialog.

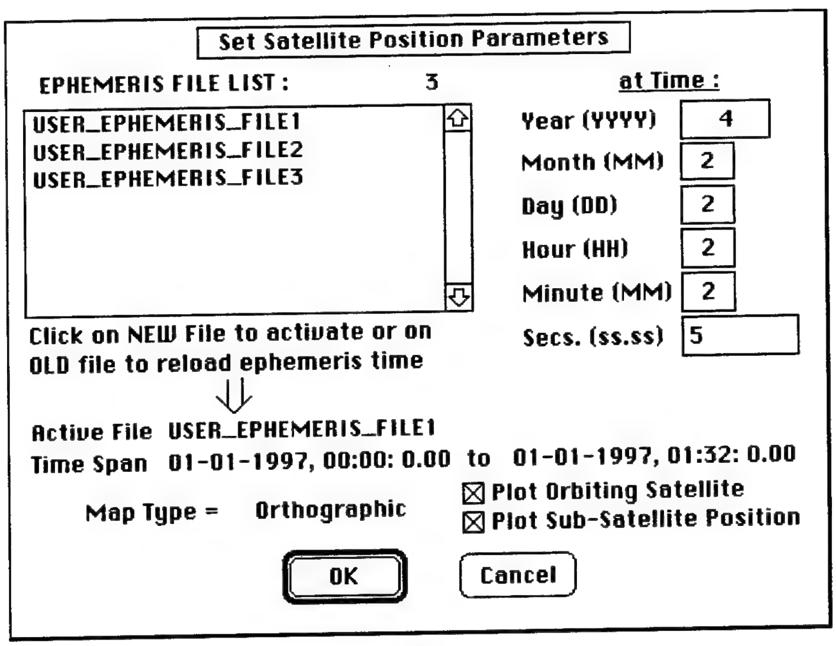


Figure 7-11. Satellite Position Dialog

Icon Options...

The small dialog seen in Figure 7-12 is brought up, allowing the user to select the size in pixels of the icons used to plot the satellite and/or sub-satellite positions. The small icon pictures are merely a reminder of what the position plot icons look like.

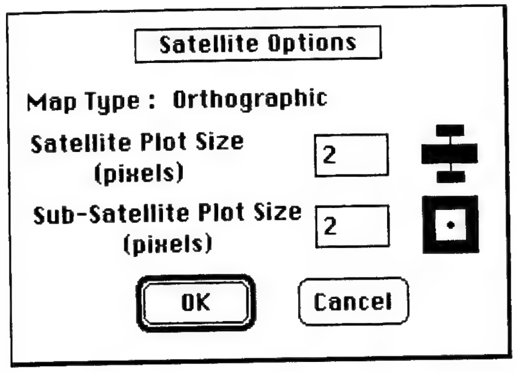


Figure 7-12. Satellite Position Icons Dialog

7.4 SATELLITE SWATH

The **Satellite Swath** menu selections are shown in Figure 7-13. This plot command is used to plot the swath swept out by the satellite FOV over a time interval by an earth-orbiting satellite.

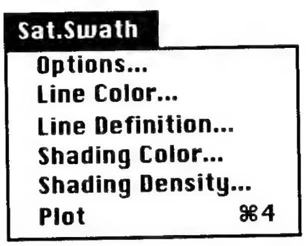


Figure 7-13. **Satellite Swath** Menu

Swath coverage is computed with one of two possible algorithms, although the choice is not made directly by the user and does not appear in any dialog or interface. Knowledge of the existence of multiple algorithms is necessary only to understand some of the output and performance characteristics of OATS. The easiest algorithm to understand is the one which sums the area covered by consecutive fields-of-view spaced at equal stepped intervals. This algorithm will handle any attitude configuration of the satellite; however, it has the disadvantages that it is slow and it does not permit an outline of the swath path to be generated. The other algorithm has neither of these problems, but it is limited to nadir pointing antennas. This algorithm computes initial and final fields-of-view, and then computes incremental coverage boxes as wide as the FOV and transverse to the satellite ground track. Since most plotted satellite swaths will overlap themselves at some point, the user should note that only the most recent orbit's swath will fully display bounding edge lines.

Options...

The dialog called by the **Options** command appears in Figure 7-14. It is not available to the user unless at least one ephemeris file has been opened (see Section 9.1). A list of files in the active

Ephemeris File List appears in the scroll list to the left of the dialog. By selecting a file, the user determines which satellite swath will be plotted. The first open file is the default selection when this dialog is initially accessed, but a different ephemeris can be selected by clicking the mouse on the name of the new file in the list. Once selected, the identity of this active file is propagated throughout most of the **Plot** dialogs. To eliminate ambiguity, the name of the active file is displayed in the *Active File* area below the list. The *Start Time* and *Stop Time* are taken from the current active ephemeris file, but may be manually reset by the user so long as the times are within the confines of the time period covered by the file. The default values of *Start Time* and *Stop Time* are the endpoints of the current active ephemeris file. The *Stop Time* can also be set according to a user supplied number of *Revolutions*. This makes it easy, for example, to specify 2 orbits and have OATS compute the plot interval with the push of a button rather than estimating it and manually assigning a *Stop Time*. If the user needs to reinitialize the times on the current active file, that file name can be clicked as if it were a re-selection of the ephemeris file. The times displayed in this dialog are linked to the times shown in the **Satellite Tracks** menu (see Figure 7-1). The *Step Size* is the time interval in seconds between successively plotted points along the track. A smaller step size implies a smoother plot, but also implies a longer execution. Settings available through the *SET ANTENNA Parameters* and *SET ATTITUDE Parameters* are discussed in Section 7.17. The *SET ATTITUDE Parameters* button is only active if the radio buttons in the center of the dialog indicate that *Use Attitude Data* is active. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all satellite FOV parameters as shown in the dialog.

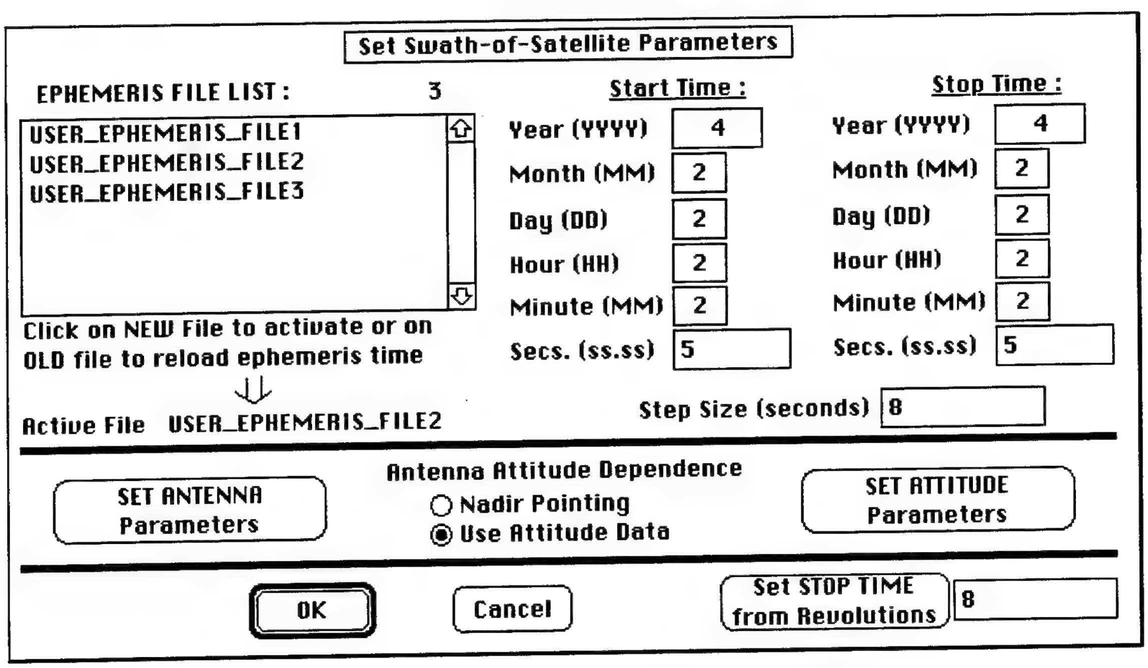


Figure 7-14. Satellite Swath Parameters Dialog

7.5 TARGET POSITION

The **Target Position** menu is shown in Figure 7-15. This plot command is used to plot a set of target icons at user-defined geographic positions. Up to 100 targets may be plotted with a single **Plot** command.

Edit List...
Icon Options...
Icon Color...
Plot ⌘5

Figure 7-15. **Target Position** Menu

Edit List...

The interface called by the **Edit List** command appears in Figure 7-16. This dialog is an interactive interface designed to allow the user to add, select, and display target data. It contains two target lists, one cataloged and one active. The cataloged list is also utilized in the **Coverage** menu (see Section 8). The *Cataloged Target List* is maintained between executions of OATS, and is intended to serve as a quasi-permanent list of targets for some user-defined overall scheme of coverage analysis. The *Active Target List* is wiped clean between OATS executions, and is intended as a dynamic and frequently changed list of targets for individual **Plot** commands. Each of these lists is displayed as a scroll list in the interface, along with a count of the number of objects in that list. Because the cataloged list is characteristically used as a source of objects for the active list, the *Select* and *ALL Select* buttons move objects from cataloged to active. The *Select* button moves a highlighted contiguous subset of targets with a single mouse click, while the *ALL Select* moves every target. Each list has a *Clear* button to eliminate all objects in the list, a *Delete* button that will eliminate a contiguous subset of the list that has been highlighted, and a *Sort* button to do an alphanumeric sort of list elements. The flexibility of this interface is enhanced by the *OPEN File* and *SAVE File* buttons, which allow an external list of targets to be read into or created from the cataloged list using the Macintosh standard file interface. The format for the target list files is covered in Section 10.3. It is a simple and straightforward format, which implies that a target list can be created by external software. An easy way to create an external target file might be with an editor. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog (including changes in the scroll lists), while *OK* will set all satellite target parameters as shown in the dialog.

To the right of the dialog interface is a *VIEW* block for individual target data. Relevant data fields include the *Name*, geodetic *Latitude*, geodetic*Longitude*, and *Altitude*. For targets already in either the active or cataloged list, data can be displayed by clicking on the target name in the scroll list.

The *VIEW* fields can also be used in conjunction with the *Add* button in the upper right of the interface to interactively, one-at-a-time, create a list of targets. Data is first manually entered into each of the four data fields. Pushing the *Add* button will then enter the new target data into each of the active and cataloged lists. Each target must have some type of name in order to clearly show its existence in the scroll lists; however, there is a great deal of flexibility built into OATS with regard to target name conventions. It is expected that targets may change frequently and that there may be no clearly unique place name associated with a target. Target names may be any non-blank field, including a simple numerical digit(s) as well as any combination string of alphanumerics. Target names may even be repeated as long as the qualifying latitude, longitude, and altitude are not all identical. When using the *Add* feature, OATS has provision for automatically naming targets. If the *Name* field is left blank, a name will be generated according to the settings for the radio buttons in the lower right corner of the interface and attached to the new target. Available schemes and examples of each include:

TYPE	EXAMPLE	DESCRIPTION
Numbered	TARG_0001	target numbers 1 through 9999
Place ID	TARG_+1241_12386	target at latitude $+12.41^{o}$ and longitude 123.86^{o}
Time ID	TARG_23-DEC-94_09:25:18	target created at 9:25:18 AM on December 23,1994 (labeled according to Macintosh internal clock)

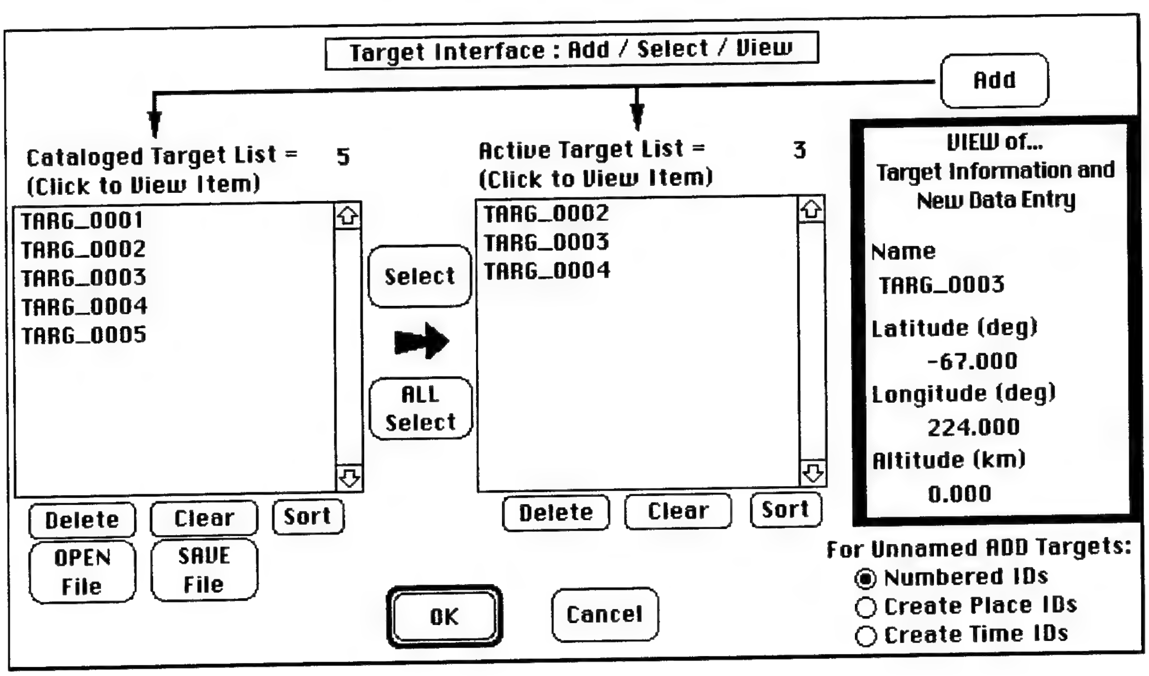


Figure 7-16. Target Interface Dialog

Icon Options...

The dialog seen in Figure 7-17 is brought up, allowing the user to select the size in pixels of the icon used to plot target positions. A wide variety of icons has been made available for plotting targets. The four basic categories are *Geometrical*, *Military*, *Civilian*, and *National Flags*, and can be selected with a radio button. Each category has a pull-down menu that can be used to select the individual icon. The *Monochromatic Icons* are single-colored, with the color being controlled by the **Icon Color** option in Figure 7-15. Flags are automatically plotted using appropriate national colors, but should not be used if OATS has been configured for black and white plotting. Note that values which are too small will result in a warning message on exiting the dialog because the target icon will become unrecognizable below a threshold, and that the threshold varies with the type of icon selected for plotting.

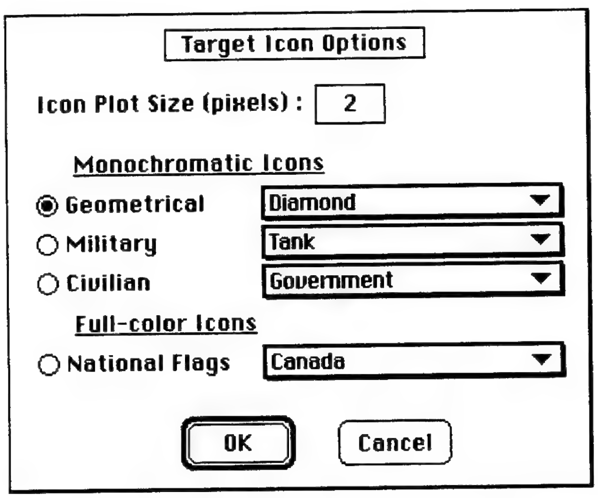


Figure 7-17. Target Icon Options Dialog

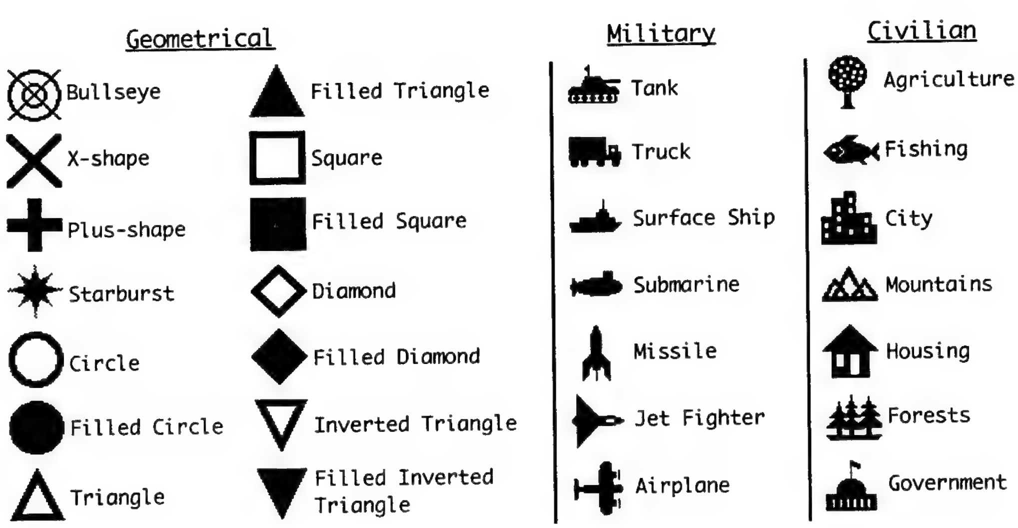


Figure 7-18. Available Monochromatic Target Icons

The current suite of monochromatic target icons is displayed in Figure 7-18. Only a percentage of possible national flags is available.

7.6 GROUND STATION POSITION

The **Ground Station Position** menu is shown in Figure 7-19. This plot command is used to plot a set of ground station icons at user-defined geographic positions.. The ground station icon is shown in Figure 7-20. Up to 20 ground stations may be plotted with a single **Plot** command.

Figure 7-19. **Ground Station Position** Menu

Figure 7-20. Ground Station Position Icon

Edit List...

The interface called by the **Edit List** command appears in Figure 7-21. This dialog is an interactive interface designed to allow the user to add, select, and display ground station data. It is very similar to the interface used for target lists. It contains two station lists, one cataloged and one active. The cataloged list is also utilized in the **Coverage** menu (see Section 8). The *Cataloged G.S. List* is maintained between executions of OATS, and is intended to serve as a quasi-permanent list of ground stations for some user-defined overall scheme of coverage analysis. The *Active G.S. List* is wiped clean between OATS executions, and is intended as a dynamic and frequently changed list of stations for individual **Plot** commands. Each of these lists is displayed as a scroll list in the interface, along with a count of the number of objects in that list. Because the cataloged list is characteristically used as a source of objects for the active list, the *Select* and *ALL Select* buttons move objects from cataloged to active. The *Select* button moves a highlighted contiguous subset of the ground station list with a single mouse click, while the *ALL Select* moves every station. Each list has a *Clear* button to eliminate all objects in the list, a *Delete* button that will eliminate a contiguous subset of the list that has been highlighted, and a *Sort* button to do an alphanumeric sort of list elements. The flexibility of this interface is enhanced by the *OPEN File* and *SAVE File* buttons, which allow an external list of ground stations to be read into or created from the cataloged list using the Macintosh standard file interface. The format for the ground station list files is covered in Section 10.4. It is a simple and straightforward format, which

implies that a station list can be created by external software. An easy way to create an external ground station file might be with an editor. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog (including changes in the scroll lists), while *OK* will set all ground station parameters as shown in the dialog.

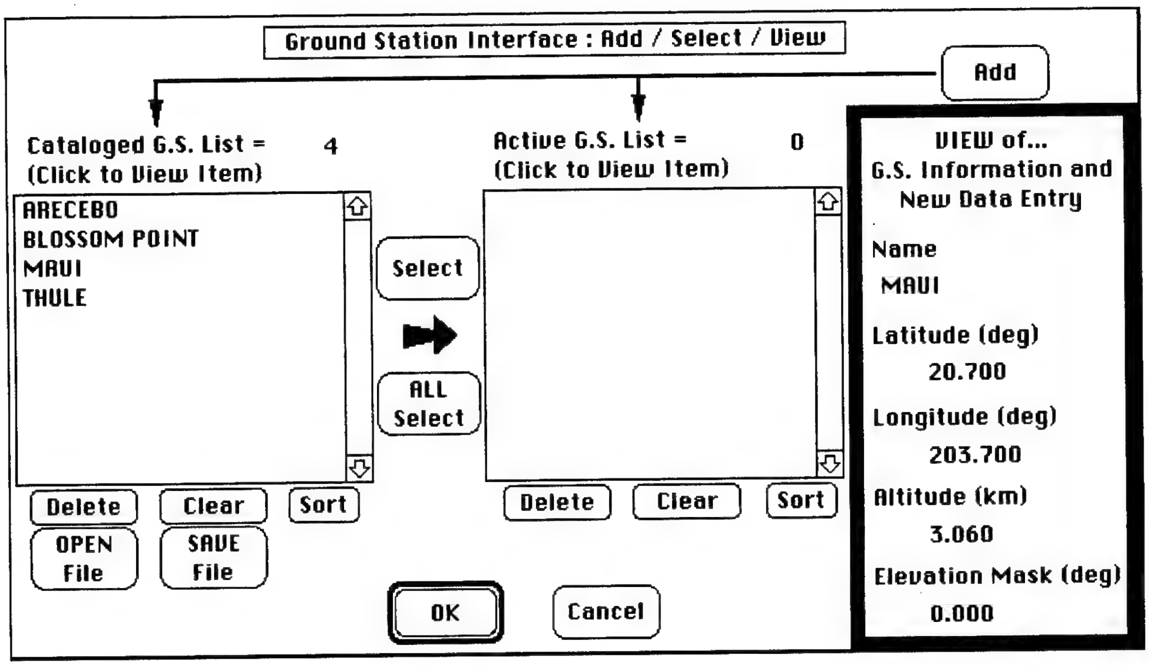


Figure 7-21. Ground Station Position Interface Dialog

To the right of the dialog interface is a *VIEW* block for the individual ground station data. Data fields include the *Name*, geodetic *Latitude*, geodetic *Longitude*, *Altitude*, and the *Elevation Mask*. For stations already in either the active or cataloged list, data can be displayed by clicking on the station name in the scroll list. The *VIEW* fields can also be used in conjunction with the *Add* button in the upper right of the interface to interactively one-at-a-time create a list of ground stations. Data is first manually entered into each of the five data fields. Pushing the *Add* button will enter the new ground station data into each of the active and cataloged lists. Each station must have some type of name in order to clearly show its existence in the scroll lists; however, there is a great deal of flexibility built into OATS with regard to naming conventions. Station names may be any non-blank field, including a simple numerical digit(s) as well as any combination string of alphanumerics. Names may even be repeated as long as the qualifying latitude, longitude, altitude, and mask are not all identical.

Icon Options...

The dialog seen in Figure 7-22 is displayed, allowing the user to select the *Icon Plot Size* in pixels of the icon used to plot ground station positions. Note that values which are too small will result in a warning message on exit from the dialog because the ground station icon will become

unrecognizable below a threshold. Ground stations can also automatically have their names plotted when the station icons are plotted. The *Plot GS Names* checkbox turns name plotting on and off. The *Set FONT/COLOR for Names* button is active only if name plotting is active. This button brings up the font dialog discussed in Section 7.17, and allows the user to control the color of text for ground station names as well as the font and print style. *Erase Name Background* allows the user to eliminate all plotted information from behind the plotted ground station name. This feature can be useful if background clutter makes the names illegible. If background is eliminated for a name, OATS accomplishes this task by plotting an opaque rectangle layer before plotting the name text. The rectangle color is selected so that it is as close as possible to the map background color.

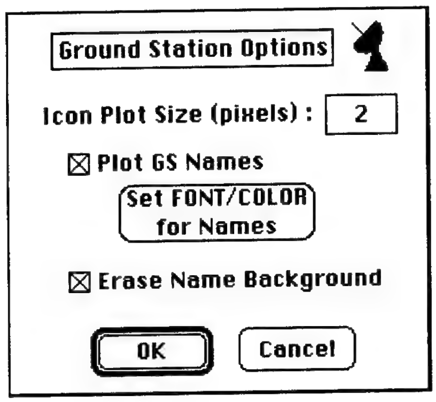


Figure 7-22. Ground Station Icon Options Dialog

7.7 GROUND STATION FIELD-OF-VIEW

The **Ground Station Field-of-View** menu is shown in Figure 7-23. This plot command is used to plot the field-of-view around every ground station in the Active Ground Station List (see Section 7.6). At this time, OATS only provides for a circular ground station field-of-view.

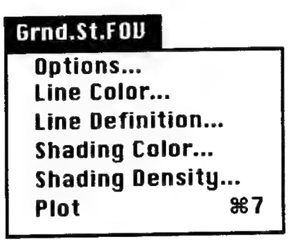


Figure 7-23. **Ground Station FOV** Menu

Options...

A ground station FOV must be linked to the altitude of a satellite that it is trying to see. OATS provides two methods of selecting this altitude for the ground station FOVs. The user may use the

radio buttons at the top of the dialog in Figure 7-24 to select a *Fixed Value of Satellite Altitude* or an *Altitude Determined from Time of Satellite Position.* If a fixed value is selected, the user manually inputs the satellite altitude in kilometers. If the satellite position is used, the altitude is derived from the time and location implied by the satellite position dialog (see Section 7.3) or the satellite FOV dialog (see Section 7.1). Because satellite position depends on an ephemeris file, a warning will be issued if the *Time of Satellite Position* option is selected without setting the time appropriately. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all ground station FOV parameters as shown in the dialog.

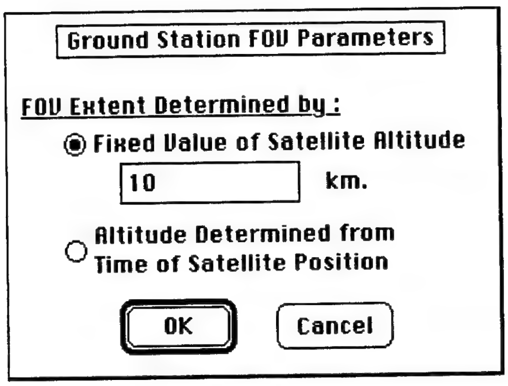


Figure 7-24. Ground Station FOV Dialog

7.8 DENSITY CONTOURS

The **Density Contours** menu is shown in Figure 7-25. Density contours are solid area shadings using colors over a world-wide mesh to show satellite coverage by the color value in each mesh element. These area contours are based on a user defined set of ephemeris files, antenna settings, and ground stations. The **Plot** command issued from this menu will plot the computed satellite coverage values contained in a file derived using the **Coverage** menu as discussed in Section 8.2. It is strongly suggested that first time users master the techniques needed to produce this file before proceeding with plotting of density contours. OATS is also capable of plotting density contours for an externally created file with the proper format. Formats for both external and internal contour files are discussed in Section 10.7. Choice of the **Plot** command will first bring up a standard Macintosh interface from which the user must select a computed coverage file. If the file does not have expected OATS-file formatting, an alert message will appear to inform the user that the file will be treated as an external contour file. The product color mapping will be plotted overlying any data previously existing in the Graphics Window. A continental outline map (see Section 7.12) makes a very effective background for a density contour plot. Because colors are additive, it is recommended that density plots be made over maps using a white background with all black line colors.

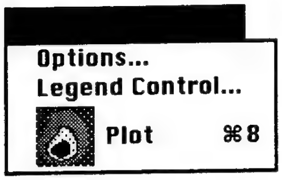


Figure 7-25. **Density Contours** Menu

Options...

The dialog that results from the **Options** command appears in Figure 7-26. It is designed as an interactive interface to allow the user to set the parameters and colors employed when plotting density contours. Central to this interface is a non-standard scroll list of the contour values and a swatch of their associated color. Contouring is performed such that each level listed represents a range of coverage values, with the value shown equaling the lowest end of the range for a given color. The control buttons to the right of the color/value scroll list are used to modify the contour values, and the control buttons to the left of the list are used to modify the colors associated with the values. Each color value has a small button with a letter. These letters are used as local IDs within the scroll list, and are required when modifying a single color/value. At the top of the scroll list are buttons that allow the user to *Scroll Up* though the list one value at a time or to go directly to the *Top* of the list of values. Similarly, at the bottom of the scroll list are buttons that allow the user to *Scroll Down* though the list one value at a time or to go directly to the *Bottom* of the list of values. The number of coverage values in the scroll list is displayed at the top of the list.

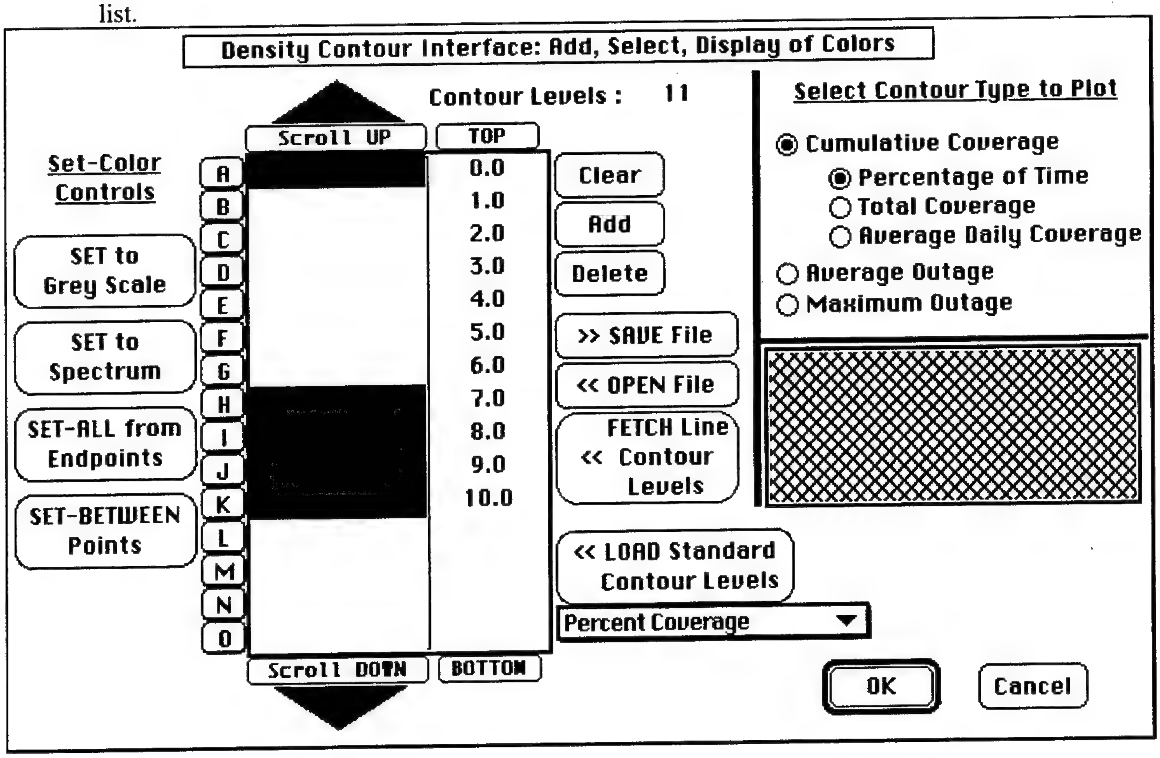


Figure 7-26. Density Contour Interface Dialog

To plot density contours, the user must first select the *Contour Type* from the radio buttons in the upper right corner of the interface dialog. All five possible types are available in the files produced by the **Coverage** menu. The *Average Outage* and *Maximum Outage* are given in terms of minutes per day that a mesh region is not covered (i.e. outage means mesh region is "out of view"). The *Cumulative Coverage* (time mesh region is in view) can be expressed as a *Percentage of Time*, as the *Average Daily Coverage* in minutes, or as the *Total Coverage* in minutes.

Contour values can be loaded into the scroll list in a variety of ways. The *Load* button will retrieve one of five sets of *Standard Contour Levels* that can be selected from the pull-down menu next to the button. These sets of standard values are maintained along with their color settings in OATS largely as a service to first-time OATS users who are uncertain of what a good set of contour values might be. They are a good starting point for a set of coverage values, which the user can then adjust to his own needs. Values can be retrieved from an external file by an *OPEN File* command (see Section 10.6 for file formats). Correspondingly, a favorite set of values in the scroll list can be saved to a file using the *SAVE File* button. OATS also performs line contour (see Section 7.9) plots, which use a separate data base of contour values than those used for density contour plotting. If desired, the density contour values can be set equal to the line contour values with the *FETCH Line Contour Levels* button. *Clear* will eliminate all values in the scroll list. *Delete* will bring up the supplemental *Delete Level ID* dialog shown in Figure 7-27, which can be used to enter the single character local ID found to the left of the color swatches. The *Add* button allows the user to enter single new contour values with the supplemental *Value to Add* dialog seen in Figure 7-27. Whenever a new value is added to the color/value list, the list is sorted by value and the color of the new value is set to gray.

Each color can be set individually with the lettered local ID button. Clicking on one will invoke the standard Macintosh Color Picker Dialog Box (Reference 8). The Picker dialog varies between systems, but usually presents a color wheel, a brightness scroll bar, and numerical color settings that can be used to set any color. The user should note that although the Picker is an easy way to set colors, any color set using the Picker will be rounded to whichever of the 256 in the look-up table is closest. As usual, the *Cancel* button will nullify any color settings changed in this dialog and the *Set* button will retain them for OATS plotting functions. All color settings are saved between OATS executions.

The *SET to Gray Scale* button will convert all color swatches to a set of gray values running from black to white. The *SET to Spectrum* will convert all color swatches to a set of pre-selected color

swatches running through the rainbow colors of red, orange, yellow, green, blue, and violet. There is an upper limit of 16 colors available in this fashion. After setting the single colors at the top and bottom of the scroll list, the full range of colors can be set using the *SET-ALL from Endpoints* button. This could be used for instance to set color swatches ranging from white to blue with interpolated values between the extremums. In a similar fashion but on a smaller scale, the *SET-BETWEEN Points* button can be used to interpolate colors between any two color/values. The *Letter IDs of Endpoints* dialog seen in Figure 7-27 will be displayed, allowing the user to enter any two local IDs to use as endpoints in the color interpolation.

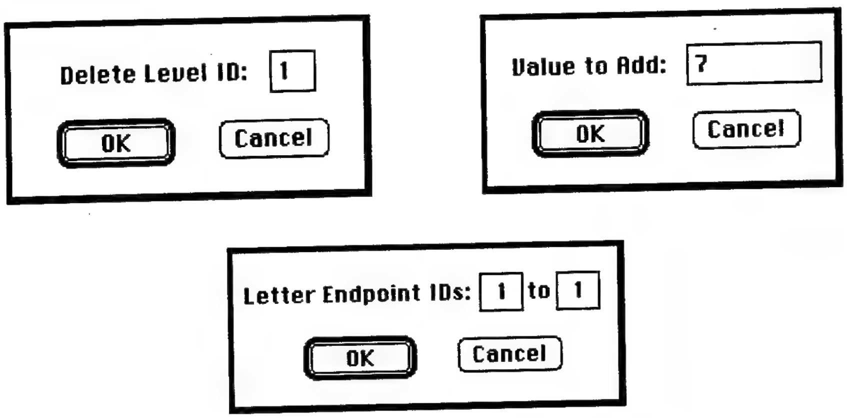


Figure 7-27. Density Contour Interface Supplemental Dialogs

Legend Control...

The dialog that comes up with the **Legend** command appears in Figure 7-28. It is used to provide control over the appearance of the legend that describes the density contours. The most basic control comes from a pair of radio buttons under *Legend Display* that turn the legend *On* or *Off*. The *Legend Location* allows the user to manually set the position of the legend by specifying the location in pixels of the *Top* and *Left* corner of the legend box. This can be important, because the plot layer used to show the legend typically covers up some small portion of a density plot. It is best to manipulate plot settings so that no coverage occurs or the coverage is over a non-essential area. The *Set to Default* button will compute default values for the legend position settings, which will place the legend box in the upper left corner of the user's plot. Each level will have a color swatch and a value like those seen in the dialog in Figure 7-26. Labeling of the swatch values can be *As INTEGER Values* or *As FLOATING PT Values*, according to the settings of the radio buttons provided. The *Set Levels FONT* button will call up the utility dialog discussed in Section 7.17 to allow the user to set the color and font style of the value labels. Font size is a critical value because the legend is made just large enough to accommodate the required number of color levels at the requested font. All parameters set from this dialog are preserved between executions of OATS. The *Cancel* button will return to the main menu without recording any of

the parameter changes made in this menu, while *OK* will set all legend parameters as shown in the dialog.

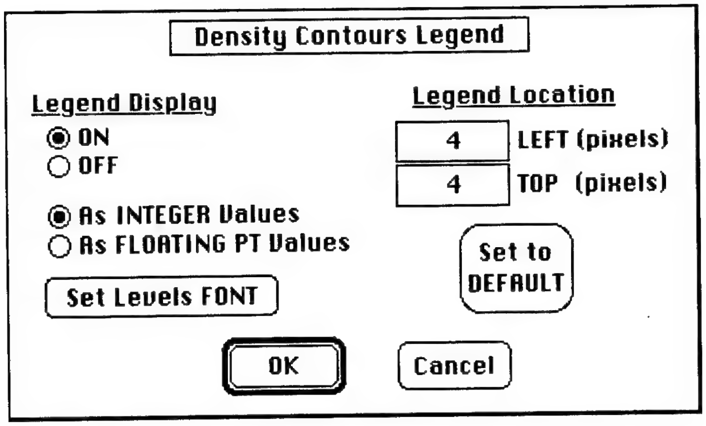


Figure 7-28. Density Contour Legend Dialog

7.9 LINE CONTOURS

The **Line Contours** menu is shown in Figure 7-29. Line contours are isochrones connecting elements of a world-wide mesh that show satellite coverage by value of each mesh element. These line contours are based on a user defined set of ephemeris files, antenna settings, and ground stations. The **Plot** command issued from this menu will plot the computed satellite coverage values contained in a file derived using the **Coverage** menu as discussed in Section 8.2.2. It is strongly suggested that first time users master the techniques needed to produce this file before proceeding with plotting of line contours. OATS is also capable of plotting line contours for an externally created file with the proper format. Formats for both external and internal contour files are discussed in Section 10.7. Choice of the **Plot** command will first bring up a standard Macintosh interface from which the user must select a computed coverage file. If the file does not have expected OATS-file formatting, an alert message will appear to inform the user that the file will be treated as an external contour file. The line contours will be plotted overlying any data previously existing in the Graphics Window.

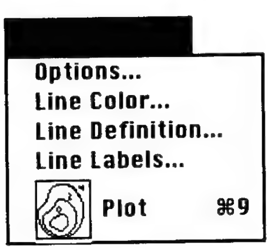


Figure 7-29. **Line Contours** Menu

Options...

The dialog that results from the **Options** command appears in Figure 7-30. It is designed as an interactive interface to allow the user to set the parameters employed when plotting line contours. Central to this interface is a standard scroll list of the contour values. Contouring is performed such that each level listed represents a range of coverage values, with the value shown equaling the lowest end of the range for a given level. The control buttons to the right of the scroll list are used to modify the contour values. The number of *Contour Levels* in the scroll list is displayed at the top of the list. To plot line contours, the user must first select the *Contour Type* from the radio buttons in the upper right corner of the interface dialog. All five possible types are available in the files produced by the **Coverage** menu. The *Average Outage* and *Maximum Outage* are given in terms of minutes per day that a mesh region is not covered (i.e. outage means mesh region is "out of view"). The *Cumulative Coverage* (time mesh region is in view) can be expressed as a *Percentage of Time*, as the *Average Daily Coverage* in minutes, or as the *Total Coverage* in minutes.

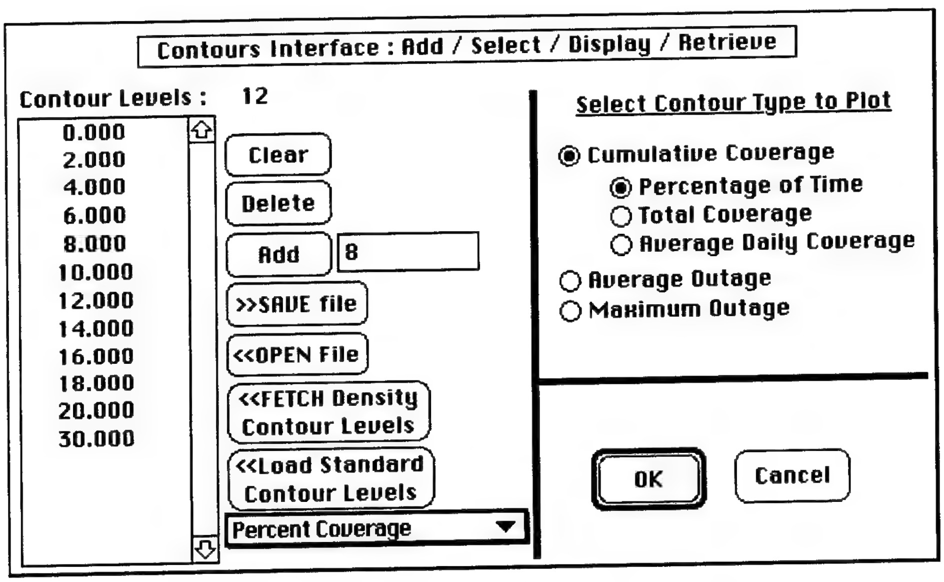


Figure 7-30. Line Contour Interface Dialog

Contour values can be loaded into the scroll list in a variety of ways. The *Load* button will retrieve one of five sets of *Standard Contour Levels* that can be selected from the pull-down menu next to the button. These sets of standard values are maintained along with their color settings in OATS largely as a service to first-time OATS users who are uncertain of what a good set of contour values might be. They are a good starting point for a set of coverage values, which the user can then adjust to his own needs. Values can be retrieved from an external file by an *OPEN File* command (see Section 10.6 for file formats). Correspondingly, a favorite set of values in the

scroll list can be saved to a file using the *SAVE File* button. OATS also performs density contour (see Section 7.8) plots, which use a separate set of contour values than those used for line contour plotting. If desired, the line contour values can be set equal to the density contour values with the *FETCH Density Contour Levels* button. *Clear* will eliminate all values in the scroll list. Single values or a contiguous set of levels can be eliminated from the list by highlighting them with the mouse and then clicking the *Delete* button. The *Add* button allows the user to enter a single new contour value which has been entered manually into the input field provided. Whenever a new value is added to the values list, the list is sorted in ascending order.

Line Labels...

OATS makes provision for the user to label the line contours for identification purposes via the dialog shown in Figure 7-31. *Labeling of Contour Values* can be turned *ON* or *OFF*, and they can be shown as *INTEGER Values* or as *FLOATING PT Values* using the radio button settings. The *Set FONT/COLOR* button will call up the utility dialog seen in Section 7.17 to allow the user to set the color and style of the value labels. The user should note that this labeling is intended as supplemental information and that little effort has been made to make the labeling algorithm robust. One label only is provided for each isochrone.

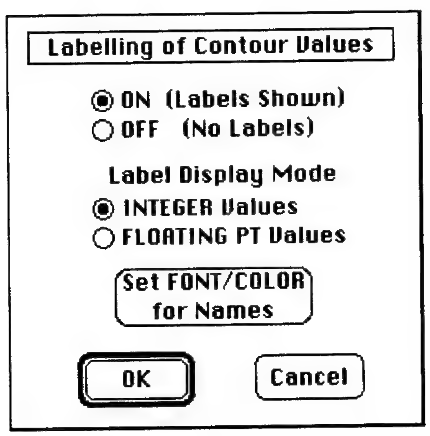


Figure 7-31. Line Contour Labels Dialog

7.10 SUN AND SHADOWS

The **Sun and Shadows** menu is shown in Figure 7-32. This plot command is used to display a sun icon, shown in Figure 7-33, at the geographic sub-solar position. There is also an option to display a sub-lunar position, whose icon is also displayed. The plot command will show the terminator line, defined lines of twilight, and the area of the earth's surface in shadow.

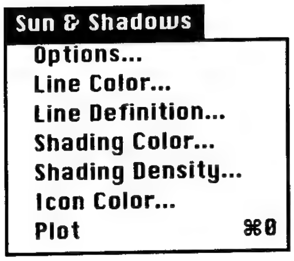


Figure 7-32. **Sun and Shadows** Menu

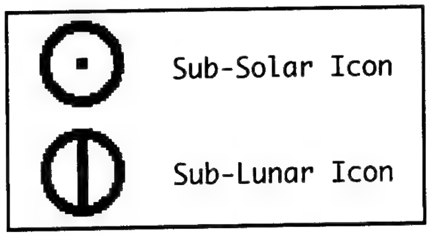


Figure 7-33. Solar and Lunar Icons

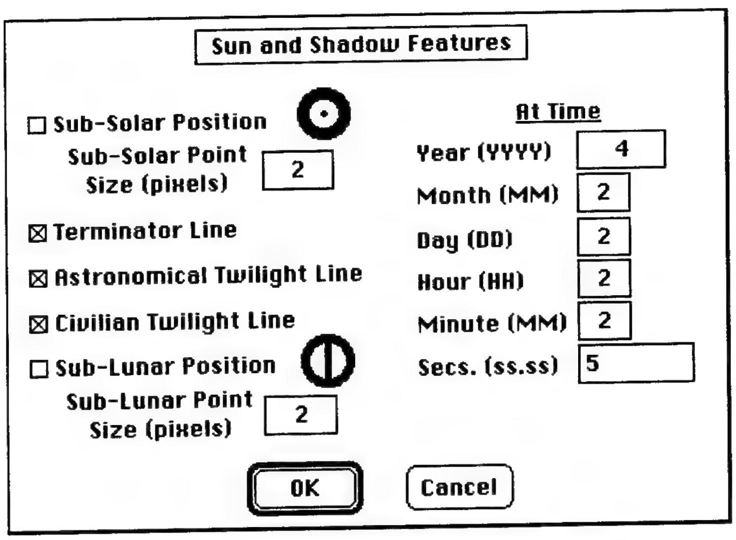


Figure 7-34. Sun and Shadows Dialog

Options ...

Figure 7-34 shows the dialog that is opened by the **Options** command. Checkboxes are available to separately turn on or off the *Sub-Solar Position, Terminator Line, Astronomical Twilight Line, Civilian Twilight Line, Shadowed Region,* and the *Sub-Lunar Position.* Next to the position checkboxes for sun and moon positions are input fields which are used to set the *Sub-Solar Point Size* and *Sub-Lunar Point Size* in pixels. Note that values which are too small will result in a warning message when the dialog is exited because the icons will become unrecognizable below a threshold. The *Time* displayed in this dialog and used for plotting sun-related features is linked to the time shown in the **Satellite Field-of-View** and **Satellite Position** menu items (see Figure 7-1); however, the time can of course be reset manually. The

Time is displayed in the *Year, Month, Day, Hour, Minute,* and *Secs* fields in the right side of the dialog. All parameters set from this dialog except *Time* are preserved between executions of OATS. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all sun and shadow related parameters as shown in the dialog.

7.11 COVERAGE SNAPSHOT

In OATS terminology, a coverage snapshot is defined as the instantaneous interaction of the fields-of-view of several spacecraft. This interaction can be quite complex depending on the number of spacecraft involved, their positions, their antenna definitions, their attitudes, and the type of interaction (unions versus intersections). Snapshots are somewhat alike to doing coverage analysis using Venn diagrams. The program provides the ability to define, freeze, manipulate, plot, and analyze coverage snapshots. Because a snapshot is really much more than a simple set of objects to plot, the menu tree that it invokes is more complex than most of the other plot options. Snapshot manipulations also cross over into the realm of coverage functions handled in Section 8--the user will find that there is a gray line dividing the plot versus coverage aspects of snapshots. The snapshot menu is at the head of the set of interfaces used to work with snapshots, and is displayed in Figure 7-35.

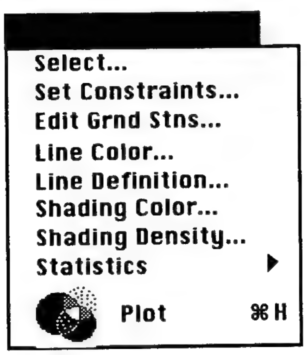


Figure 7-35. **Coverage Snapshot** Menu

Select...

This option opens the master snapshot selection dialog, shown in Figure 7-36. Snapshots are maintained within OATS as a complex list, with each list element possessing a myriad of defined characteristics. This dialog presents an overview of the *SNAPSHOT LIST*, presenting only the user-defined name for each. Supplemental information includes the count of objects in the list and a specific notation showing the *Active Snapshot* to avoid any ambiguities. From this dialog, the user is presented with six choices regarding manipulation of snapshots. *Clear List* is the simplest--it just wipes the slate clean and empties the list. *Delete* will eliminate a single active (highlighted) element from the snapshot list. *Print Summary* will open the Macintosh standard file

interface and permit the user to choose a file where a summary printout of all parameters relevant to the active snapshot are printed. An example of this appears in Section 11.

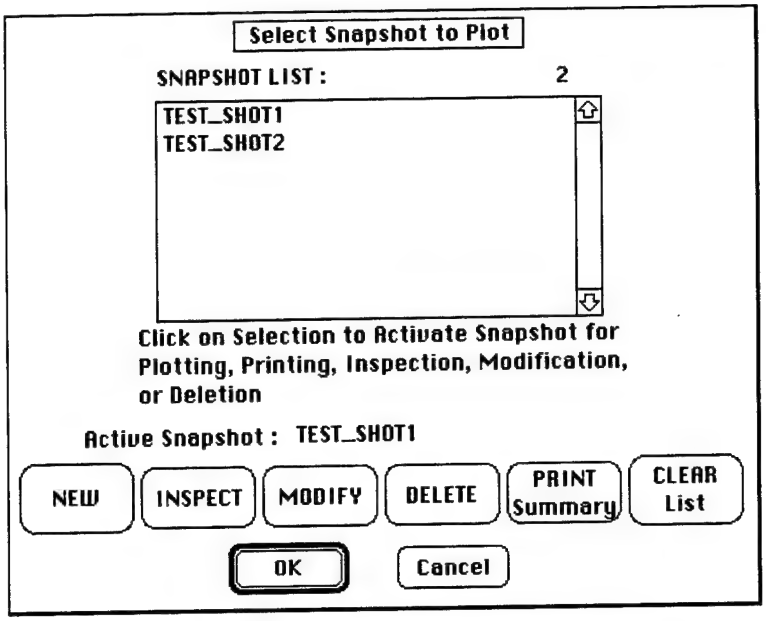


Figure 7-36. Snapshot Master Selection Dialog

The *New* function in Figure 7-36 provides an interface as shown in Figure 7-37 that enables the user to define a new snapshot. Before a snapshot can be defined, the relevant ephemeris files must be opened. If applicable, the attitude and antenna parameters need to be set for each ephemeris file via the **Set Constraints** option in Figure 7-35. This choice presents dialogs reviewed in Section 8--it is one of the cross-over areas of snapshots that was alluded to in the introduction of this chapter. If attitude or antenna parameters are changed, then all snapshots are invalidated and the list is automatically emptied. The interface in Figure 7-37 used to define a new snapshot allows the user to select a subset of the *Available Ephemeris Files*, which are displayed in the *Selected for Snapshot* list. Files can be selected into this list using the *ALL Select* button or the *Select* button to move a contiguous highlighted subset of the open ephemeris files. The *Clear* and *Delete* buttons to the right hand side of the interface are an aid in choosing the set of ephemerides that define a snapshot. *Delete* acts to eliminate a contiguous subset of listed files. All snapshots require a *Snapshot Identification* to drive the list in the master selection dialog; however, a name can be repeated multiple times. The *Available Time Span* is determined from the overlap interval of all ephemeris files *Selected* for the snapshot. No overlap implies no snapshot. *Snapshot Time* should be selected from the span, and is initially set to the beginning of the span interval. In order to aid in identifying plotted snapshots, the color of an individual snapshot may be set using the *Freeze Color* option. This attaches a user-specified color to a snapshot for the duration of its life in the program. If colors are not frozen for a snapshot, then plot color is controlled from the main

snapshot menu in Figure 7-35. The last set of parameters used to define a snapshot is quite important, and is controlled by the radio buttons to the left side of the dialog in Figure 7-37. Union or intersection of FOVs can be selected, as well as a union related to N-fold coverage regions. For example, a snapshot could be formed showing the coverage area defined by the union of the FOVs of any 2 out of 3 available satellites.

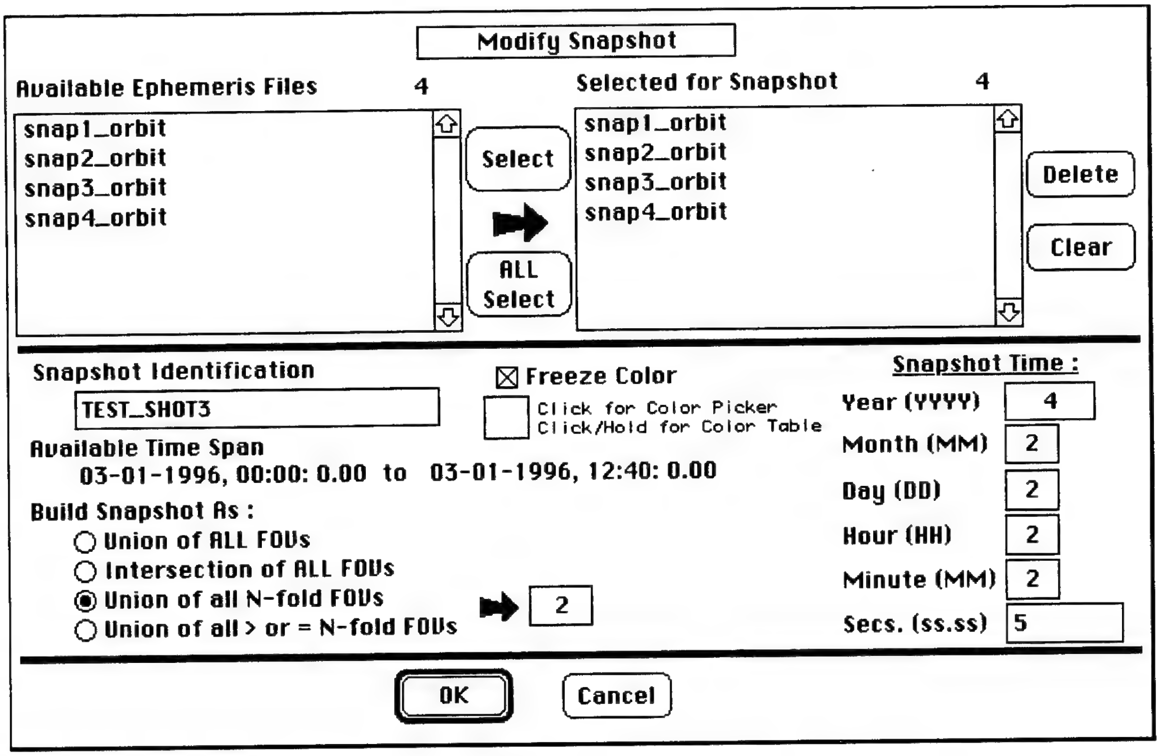


Figure 7-37. Dialog for Definition and Modification of Snapshots

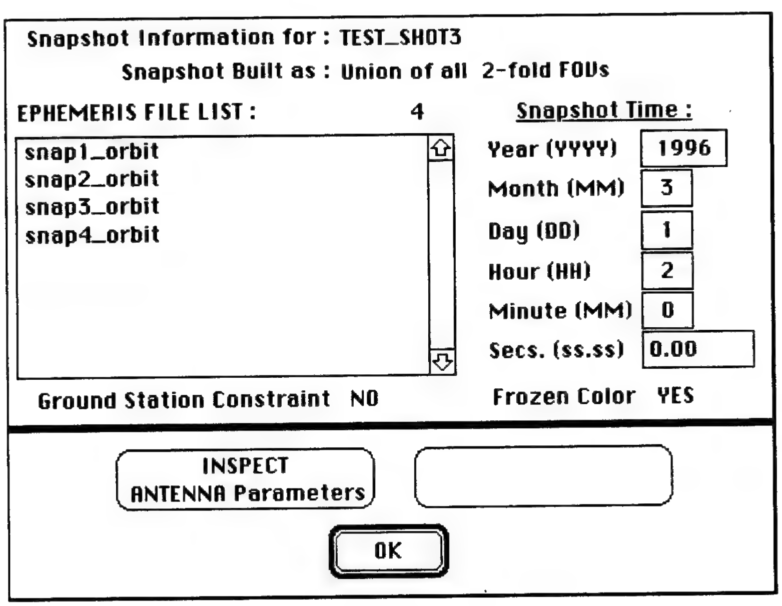


Figure 7-38. Dialog for Snapshot Inspections

The *Modify* option in Figure 7-36 also raises Figure 7-37 for the active snapshot. All of the user's previously specified choices are set and shown. The snapshot may be modified as required, and will be saved into the main snapshot list. Note that even if the name is not changed, if any data is modified from the original "new" definition, then the snapshot is considered as a new and unique snapshot.

The *Inspect* option from the snapshot master selection dialog permits viewing in the dialog shown in Figure 7-38 of all of the relevant parameters selected for a snapshot without risk of changing anything. Notably the antenna and attitude parameters selected for each snapshot ephemeris file are available.

Set Constraints...

This option is identical to ones presented under the Coverage main menu selection. It is discussed in detail in Section 8.

Edit Grnd Stns...

This option is identical to the interface discussed in Section 7.6. It is included as a snapshot option to emphasize that the ground stations can be a critical part of snapshot formulation.

Statistics

This command raises the sub-menu shown in Figure 7-39. It allows the user to compute the area covered by the active snapshot, as set in Figure 7-36.

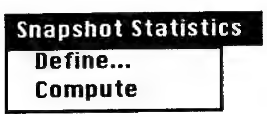


Figure 7-39. Snapshot **Statistics** Menu

Define...

The dialog shown in Figure 7-40 is presented, which allows the user to choose to print an optional *Snapshot Summary* along with the area computation. The printout is the same format as can be called for separately in the dialog seen in Figure 7-36 using the *Print Summary* button. The *Target Grid Size* determines the global grid used to compute the area covered by a snapshot. Large grid sizes make for faster computations, but smaller ones imply more accuracy.

Compute

This commands initiates the area computation. The Macintosh standard file interface will be activated to allow the user to select an output file for recording the computation. If called for by the system parameter settings (see Section 5.1), one of the tabular output windows will be opened and an echo of the output will be shown in the tabular window. The basic output for the computed area covered by a snapshot is a single line of print.

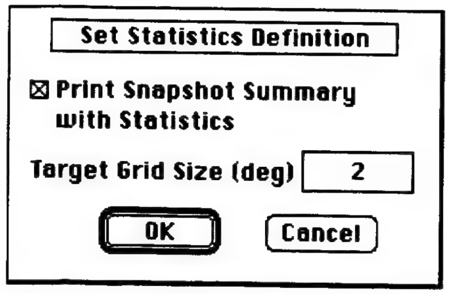


Figure 7-40. Snapshot Statistics Definition Dialog

7.12 MAP MENU

Plotting maps is an important part of OATS function because a global map almost always forms the background against which graphic coverage results are plotted. The locations of satellites, targets, and ground stations that contribute to the overall scheme of a potential coverage situation are more easily conceptualized if displayed relative to a map. Often the potential implications of a particular orbit are more easily seen if viewed from an appropriately selected perspective.

Figure 7-41. **Map** Menu

Plotting and control of maps in OATS is controlled with the **Map** menu, as displayed in Figure 7-41. **Map** is available from the **Plot** menu shown in Figure 7-1. There are seven menu selections from which to choose for control and plotting of maps.

Projections...

This command allows the user to select the map projection for an OATS plot. A map projection is the systematic mathematically defined representation of all or part of the surface of a three-dimensional spherical body (the Earth in this case) on a two-dimensional surface (paper or computer screen). All map projections will produce some level of distortion of map features, with the distortion occurring in map characteristics like area, shape, or scale. The map projection employed is usually selected based upon which distortion it is most critical to minimize. The **Projections** command will produce a multi-appearance dialog as shown in Figure 7-42. The

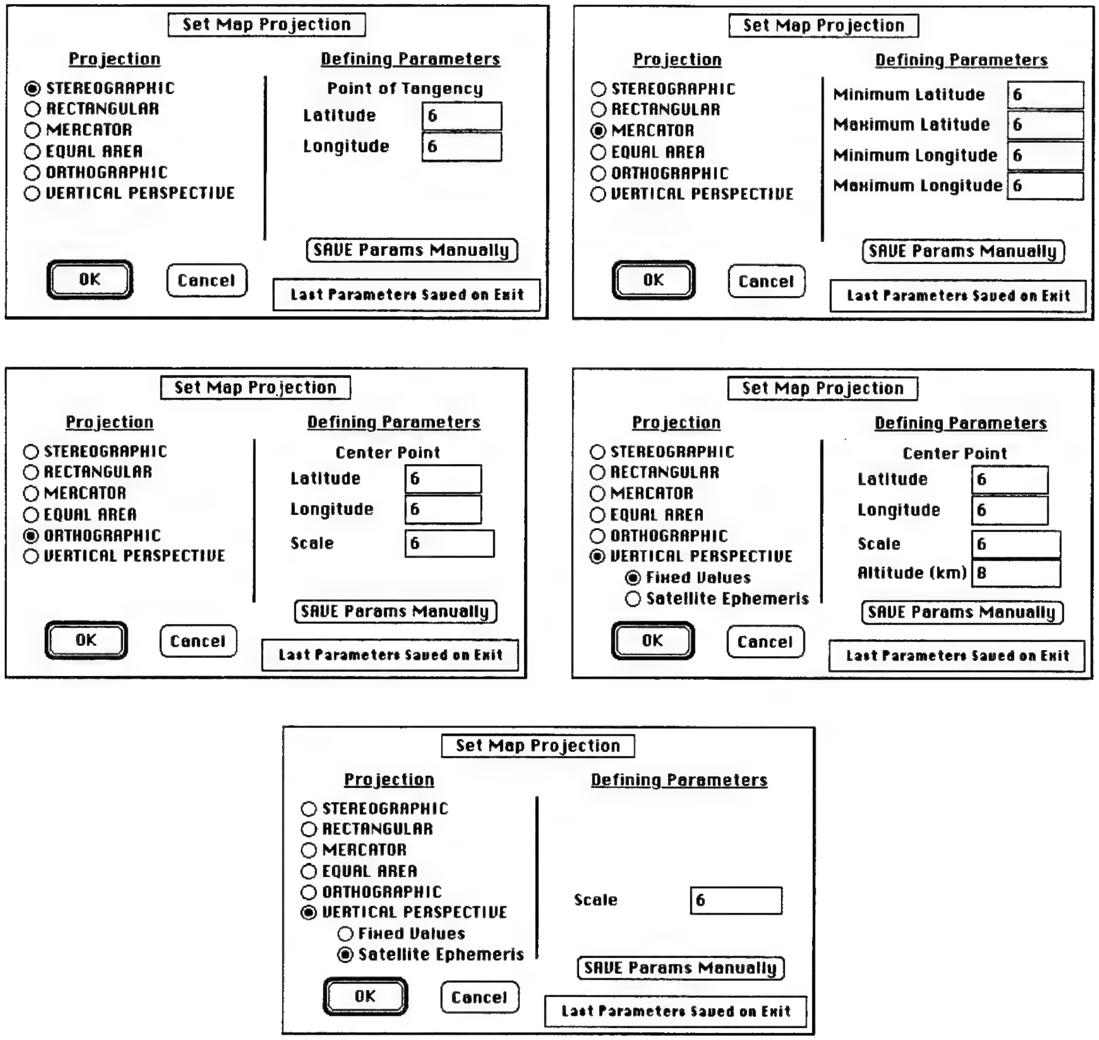


Figure 7-42. Map Projection Dialog Variations

various presentations of this dialog are shown in reduced size format merely to accommodate them together in this document. This figure presents defining parameters for the six map projections available in OATS. A brief description of each map projection is provided below, with further details available in Reference 9. Each of the six map projections can be selected via the radio button next to its name, which will show a view of input parameters appropriate to that map projection. Note that the dialog will appear the same for the *Rectangular*, *Mercator*, and *Equal Area* selections. Figure 7-43 presents a sample plot from each of the map projections. All parameters set from this dialog are preserved between executions of OATS. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this menu. *OK* will normally set and save all map projection parameters as shown in the dialog and return to the main menu, with one exception. If a *Vertical Perspective* map projection using a *Satellite*

Ephemeris is selected, a different exit path is employed as described below. Exiting this dialog using the OK will save only the map *Defining Parameters* being viewed. If the user wishes to set more than one set of parameters during a single viewing of this dialog, the *Save Params Manually* will save the set in view but will not exit the dialog.

- *Rectangular* - This projection is the first of three OATS cylindrical projections, so named because they are from a family of transformations formed by projecting the earth's surface onto a cylinder wrapped around the sphere at the Equator. Such map projections have a conceptual cut along which the projection-cylinder is cut and then unrolled onto the flat surface. The Rectangular Projection (also known as Equidistant Cylindrical) makes no attempt to minimize any map distortion; however, it is the simplest map projection to construct and understand because latitude and longitude are presented as equally scaled Cartesian coordinates. OATS requires the minimum and maximum of latitude and of longitude to define this projection. All cylindrical longitudes should fall between -360 and +360 degrees and should not exceed a total range of 360 degrees. Rectangular latitude should not exceed -90 or +90 degrees. Parameters that violate these bounds will cause an alert on exit of the dialog, and will result in uncertain results in subsequent plots. OATS defines Rectangular plots such that in a square Graphics Window, the latitude scale equals the longitude scale implied by the user's choice of bounds.
- *Mercator* - The Mercator projection is another cylindrical map projection that preserves map scale near the Equator. OATS requires the minimum and maximum of latitude and longitude to define this transform. Two major drawbacks of the Mercator projection are that there is significant area distortion near the poles, and that the poles themselves are an infinite distance from the Equator because vertical distance is scaled according to the secant of latitude. Consequently, the input latitude bounds must be less than +90 and greater than -90 degrees.
- *Equal Area* - This is the third of OATS' cylindrical map projections, and is also known as the Lambert Cylindrical Equal-Area projection. It preserves area size of map features by making a perspective projection of the Earth sphere onto the encircling projection-cylinder using the sine of the latitude. Its major drawback is that there is extreme shape and scale distortion close to the poles. Latitude bounds should not exceed -90 or +90 degrees.
- *Stereographic* - This map projection presents a view of the sphere projected onto a plane tangent to (one point touching) the sphere. It presents a view of exactly half of the sphere, and requires input of the latitude and longitude of the point of tangency. This projection preserves the shape of map features (conformal) and relative directions at any given point (azimuthal). Its major drawbacks are the area and scale distortions near the edges.

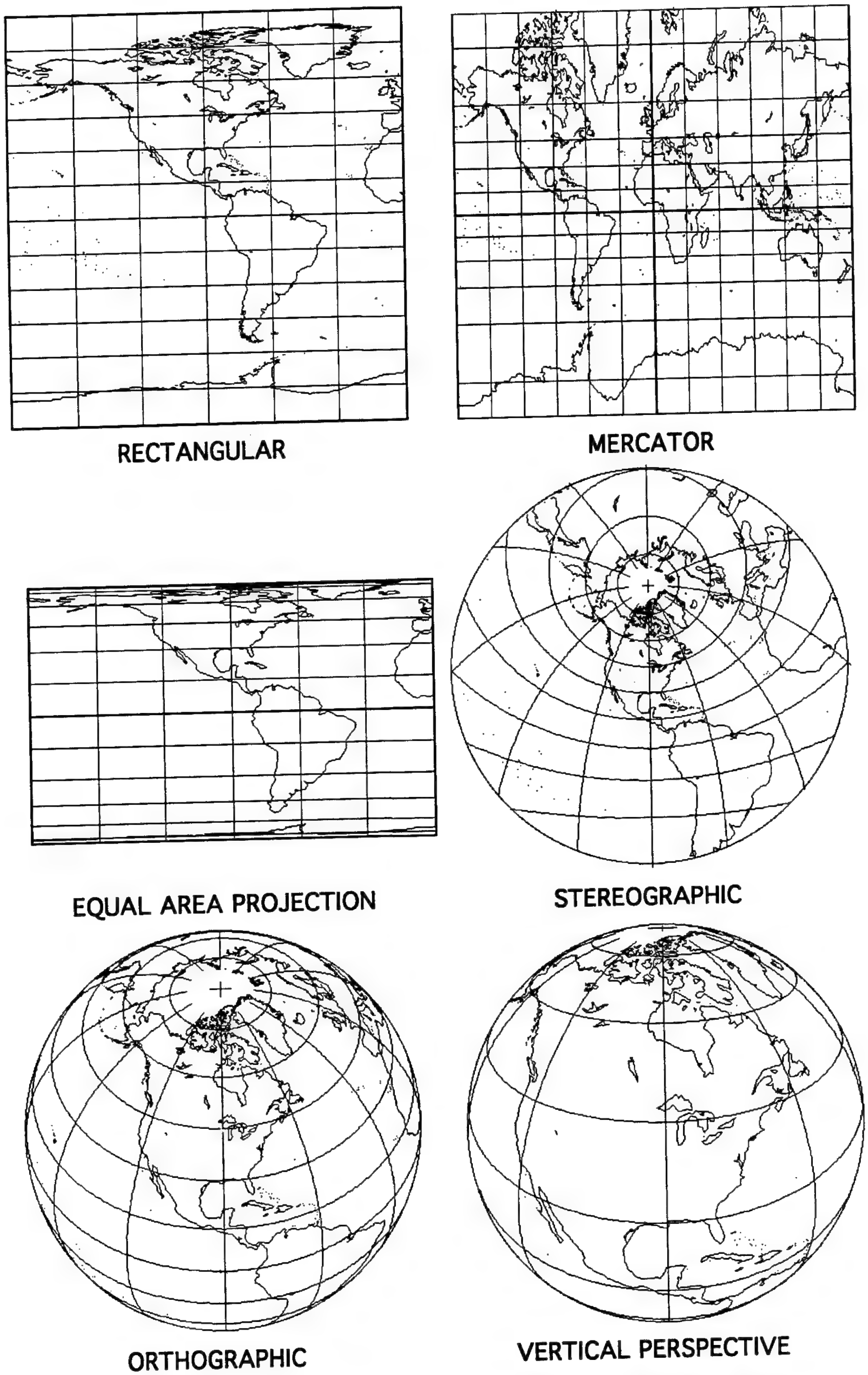


Figure 7-43. Sample Views of Available OATS Map Projections

- *Orthographic* - The orthographic map projection is equivalent to a perspective projection viewed from an infinite distance. Zero distortion exists only at the center, with significant distortion near the edge of the hemisphere that is visible. This projection is useful because it resembles the earth from a perspective view while maximizing the visible surface. It provides a very reasonable approximation to a three-dimensional view of the sphere and can be used effectively for showing the space track of a satellite. OATS requires the latitude and longitude of the center point of the view (actually the tangent point of the projection plane). A *Scale* factor is also required to determine the size of the spherical plot. A scale of 1.0 will cause the orthographic projection to fill the available plot window. Values smaller than 1.0 are usually used to allow room to plot space tracks; however, values greater than 1.0 are acceptable.
- *Vertical Perspective* - This map projection mimics the view of the Earth as seen from a nadir pointing satellite in orbit. Distortion is minimized at the center only, and grows as the edge is approached. It is possible with the radio buttons provided to select whether the viewing point comes from *Fixed Values* of *Latitude*, *Longitude*, and *Altitude* provided by the user in Figure 7-42, or from a *Satellite Ephemeris*. In either case, a *Scale* factor is required similar to that used for the orthographic projection. If *Satellite Ephemeris* is selected, and if one or more ephemeris files have been opened (see Section 9.1), then an additional dialog that is discussed in Section 9 will be displayed when the Map Projection dialog is exited. This dialog allows the view point to be selected as any point in any of the open ephemeris files. Either *OK* or *Cancel* from this dialog will exit to the main menu.

General Options...

This command presents the dialog shown in Figure 7-44 which allows the user to select the optional details defining a plotted map. *Map Appearance* allows a choice of a *World-View Map*, where green land masses are displayed on blue ocean background, or of a *Continental Outline Map*, where borders of land masses are plotted on a uniformly colored background, or of a *World-View + Outline* combination of the two which highlights the outlines of the solid green land masses. The *Map Source* radio buttons allow selection of the data which is used to plot the map boundary lines. Both the *High Resolution* and *Low Resolution* sources will draw on self-contained databases of latitude/longitude pairs that define the coastlines of land masses. The principal difference between these two sources is that a low resolution plot will execute faster, but will omit many small islands and delete some details from continental coastlines. A *User-Supplied Map File* can also be used as the source of plot data. The format for such a file is discussed in Section 10.5. The *Horizontal* and *Vertical Map Margins* can be set as pixel parameters to allow a pre-defined minimum white space around a plotted map. This white space is helpful when cutting and pasting OATS-generated pictures to other applications (see Appendix B). A checkbox is provided

to plot an *Outline Border for Map* which is the same thickness as that selected for the thickness of coordinate lines using the **Line Definition** option in Figure 7-41. All parameters set from this dialog are preserved between executions of OATS. The *Cancel* button will return to the main menu without recording any of the parameter changes made in this dialog, while *OK* will set all map option parameters as shown in the dialog.

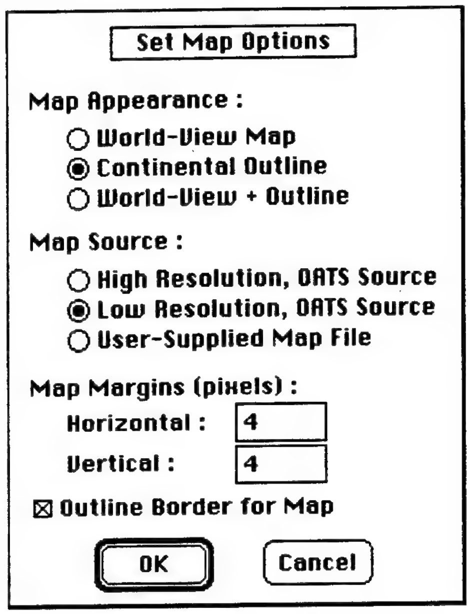


Figure 7-44. Map General Options Dialog

Label Options...

OATS provides generous flexibility with regards to labeling of plotted maps. Figure 7-45 has a checkbox to turn on or off the *Lat/Lon Coordinate Grid*, with parameter inputs provided to set the *Latitude Grid Width*. and *Longitude Grid Width*. An additional checkbox permits coordinate labeling to be turned on or off. Labels are attached to every coordinate grid line. Under some conditions--most notably cases like orthographic plots where some labels must be drawn across the face of the map--it is desirable to limit plotted labels to user-specified ranges so that some labels are omitted. The *MAX* and *MIN* of *label limits* is the mechanism that OATS uses to restrict label plotting. In order to disregard such limits, merely assure that they exceed the appropriate upper and lower limits of the plot. The *Set Coordinate Labels FONT* button raises the font dialog from Section 7.17. The checkbox to *Highlight Lat/Lon Zero-Pt Lines* can be used to identify the Equator and the Prime Meridian. These lines are then plotted one pixel thicker than ordinary coordinate lines so that they stand apart. The *Force Longitude Labels* option is useful only for selected map projections as indicated in the dialog. For cylindrical coordinate projections, labels are placed outside the edges of the map and this option is of no importance. For the other map

projections as noted, normal procedure is to place longitude labels along the parallel of latitude closest to the center of the plot field. If the *Force* option is elected, labels are placed along the equator regardless of where it lies in the plot.

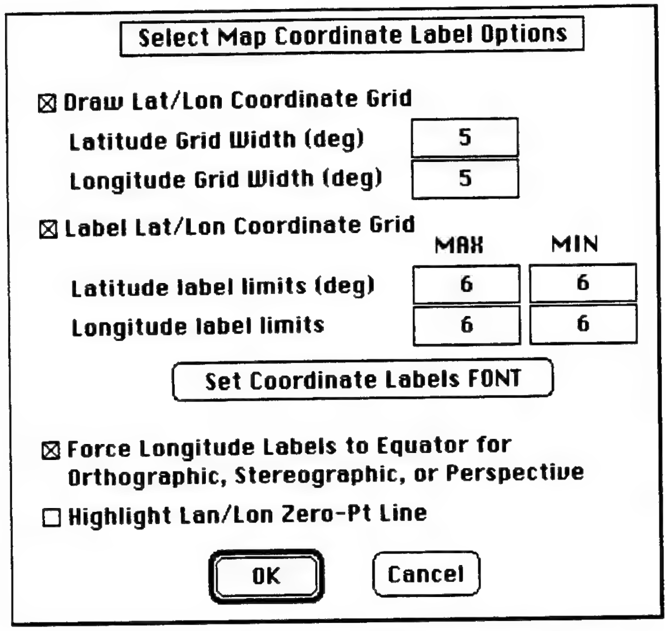


Figure 7-45. Map Coordinate Label Options Dialog

Colors

This menu selection presents the third level of menu options shown in Figure 7-46 which allows the user to individually select the colors used for **Geographic** (land mass outline) lines, **Coordinate** lines, **Background** shading for continental outline maps, and for the **Map Border**. All of these color-related selections will bring up the Color Selection utility dialog discussed in Section 7.17.

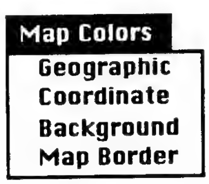


Figure 7-46. **Map Colors** Sub-Menu

Line Definition

This menu selection presents the sub-sub-menu options shown in Figure 7-47 which allows the Geographic or Coordinate Line Definition to be set using utility dialogs discussed in Section 7.17

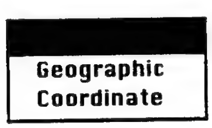


Figure 7-47. **Map Line Definition** Sub-Menu

Standard Maps

This menu selection presents the third level of menu options shown in Figure 7-48. The use of standard maps provides a mechanism to **Save** and **Retrieve** frequently used background maps. While the process of just plotting a map is fairly brief, the entire process of deciding on projection, colors, and options can be very repetitive and time-consuming for some analyses. Retrieval of a background map which has been previously plotted and fine-tuned saves time. If necessary, features like ground stations or targets or even an orbital plot can be saved as part of a standard map; however, they cannot be changed or removed once saved with a standard map. When a **Retrieve** is done, all crucial parameters defining a map projection are also retrieved and read into OATS. The **Save** command brings up the Macintosh standard file interface dialog so that the user may specify name and directory for the standard map file to be saved. *OK* will save the map in the Graphics Window, while *Cancel* will return to the main menu. A standard map can be imported into a plot frame in the Graphics Window that is a different size than that used to create it (see Section 4.5); however, standard maps shrink well and expand poorly. As a rule, when creating a standard map they should be constructed at the maximum reasonable window size and using a 1-by-1 page setting (see Figure 5-12). It is very important to recognize that before a standard map is created, the layers that contribute to it should be manually combined. Otherwise, only the single top layer is saved to the map file. Note that the **Save** or **Open** menu selections done from the **File** menu (see Section 5.2) perform a function similar to the standard map commands; however, one critical difference is that the parameters defining the map projection are not propagated into or taken from the saved plot file.

Figure 7-48. **Standard Maps** Sub-Menu

Plot Map

This menu selection will initiate execution of a map plot as defined by the dialogs in the previous discussion of set-up procedures for maps. This command can also be initiated with the command-key **⌘-M**. With one exception, the **Plot Map** command will immediately commence to plot your map in the Graphics Window, regardless of whether the window is visible or if it is the active window. The exception comes when the user has specified that an external file will be used to define the map (see Figure 7-45). In this instance, the notice shown in Figure 7-49 will appear. After clicking on this notice, the Macintosh standard file interface dialog will be displayed and allow the user to select the map file. If the world view plus outline is selected, the user will be asked to select a file twice. Although cumbersome for generic maps where both selections would

be the same user map file, the double file selection makes possible the option of a background world view map and an overlying political map.

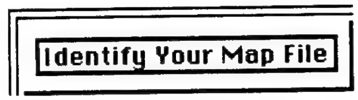


Figure 7-49. Map File Identification Notice

7.13 <u>ZOOM PROCESSES</u>

Zoom will bring up the sub-menu shown in Figure 7-50. This set of commands will change the display size of plotted data. Make special note that the zoom processes do NOT change the resolution of plotted data, nor do they change the size of the Graphics Window. They just make the image easier to see by making it larger or more compact. For example, an image at extreme magnification will start to show individual pixels in the plot--it will not show more details. Zoom is not a substitute for a more focused plot area. If what the user seeks is a "better" plot with clearer detail, it will be necessary to manipulate the scale or plot parameter limits to confine the area of interest prior to executing a plot.

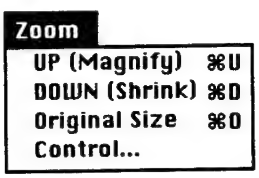


Figure 7-50. **Zoom** Menu

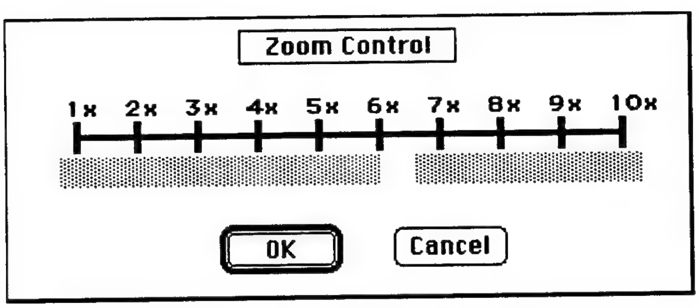


Figure 7-51. Zoom Control Dialog

The **UP** menu selection causes the plot display to be magnified, and can be accessed with the **⌘-U** command key. In response to this magnify command, the cursor will be replaced by a locator icon cross-hair (see Section 7.14). The user then positions this cross-hair over the center of the area of the display that is to be enlarged, and clicks the mouse button to initiate a zoom. The **DOWN** menu selection causes the plot display to shrink, and can be accessed with the **⌘-D** command key. Either of these commands requires that plotted data lie in a single layer. If this is not the case, multiple layers will be added together before zooming. **Original Size** will return the plot display to the original size, and is also available

through the ⌘-O command key. **Control** brings up the dialog shown in Figure 7-51 which allows the user to change the amount of magnification or reduction via a standard Macintosh control slide. At maximum value, the image can be shown as 10 times its original plot size or at 10 percent of its original size. The power can be changed in increments of $^1/_4$ power.

7.14 LOCATOR MODE

Locator Mode enters OATS into a mode where the latitude and longitude of a point on a plot indicated by the cursor is interactively computed and displayed. This mode can be accessed from the **Plot** menu or with an ⌘-L command key. When the **Locator Mode** command is issued, the cursor changes to the locator icon specified by the settings discussed in Section . Locator icons are types of cross-hairs that allow the user to identify map locations with single-pixel resolution. A choice of three is available. The latitude and longitude are displayed in degree measure in a small dialog located in the upper left corner of the monitor. Its location is not connected to the Graphics Window. If the cursor is pointing outside of the defined boundaries of the map or plot display, the coordinate fields will show "?????" to indicate no coordinate available. If no plot has been made, then coordinates will not be defined anywhere within the Graphics Window. Locator mode works for all map projections. To exit Locator Mode, simply move the cursor to a location outside the Graphics Window such as into the menu bar at the top of the computer screen. The cursor will be returned to the normal pointer arrow and OATS will return to the main menu.

7.15 MASTER SETTINGS

The **Master Settings** menu is shown in Figure 7-52. This plot command makes no plot--rather it gives the user a means to display all similar types of plot settings so they may be viewed and changed in a single dialog. For example, while it is common to have a situation where only the size of the sun position icon is of interest, there may be other times when it is more valuable to be able to compare all of the icons at once and set them according to the size of each other.

Figure 7-52. **Master Settings** Menu

Plot Icon Sizes...

As discussed throughout Section 7, all individual plot processes have individual controls that can be used to change the size of plotted icons. The **Plot Icon Sizes** menu selection displays the

dialog shown in Figure 7-53. It provides the user a master control dialog that can be used to set the size of all plotting icons, as well as provides a comprehensive display and identification of all plot icons. All icon sizes are in pixels. To the right of the dialog is a set of radio buttons that allow the user to select a *Locator Icon*. This icon is used as a cross-hair in place of the cursor for zoom magnification (see Section 7.13) and in Locator Mode (see Section 7.14).

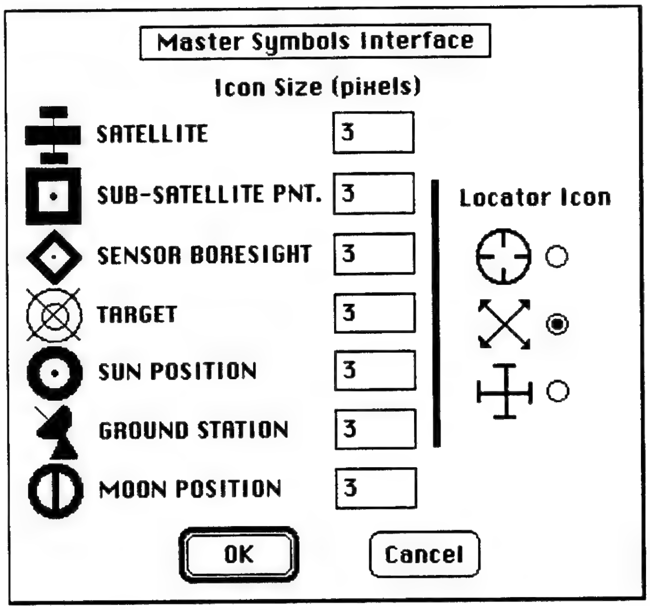


Figure 7-53. Master Symbols Interface Dialog

Plot Colors...

As with symbols, all individual plot processes have individual controls that can be used to change the colors of plotted icons, lines, and shaded regions. The **Plot Colors** menu selection displays the dialog shown in Figure 7-54, which provides the user a master control dialog that can be used to set all the program colors. More importantly, it provides the user with a simultaneous summary display of all colors. Note that it also shows pictures of all the icons with the appropriate color control. Each of the color swatches is an active control. Using the mouse to click and hold on a swatch will provide a table of 256 colors, from which one can be selected. Alternatively, a simple click will bring up the standard Macintosh color selection interface for the machine being used--typically a color wheel. Button controls exist at the bottom of the interface to reset all colors to pre-selected defaults. Defaults cannot be altered by the user. While there is no set of colors that can be fixed that will satisfy all of the possible uses of OATS, the default group of colors has been chosen to be internally consistent with a majority of OATS' general purpose functions. All user color settings and of course the defaults are maintained between OATS executions. Color can be eliminated from and/or restored to plotting functions, effectively rendering a gray scale to all plots

and displays. Similar results can also be achieved by manipulating the Macintosh monitor control under the system's control panels.

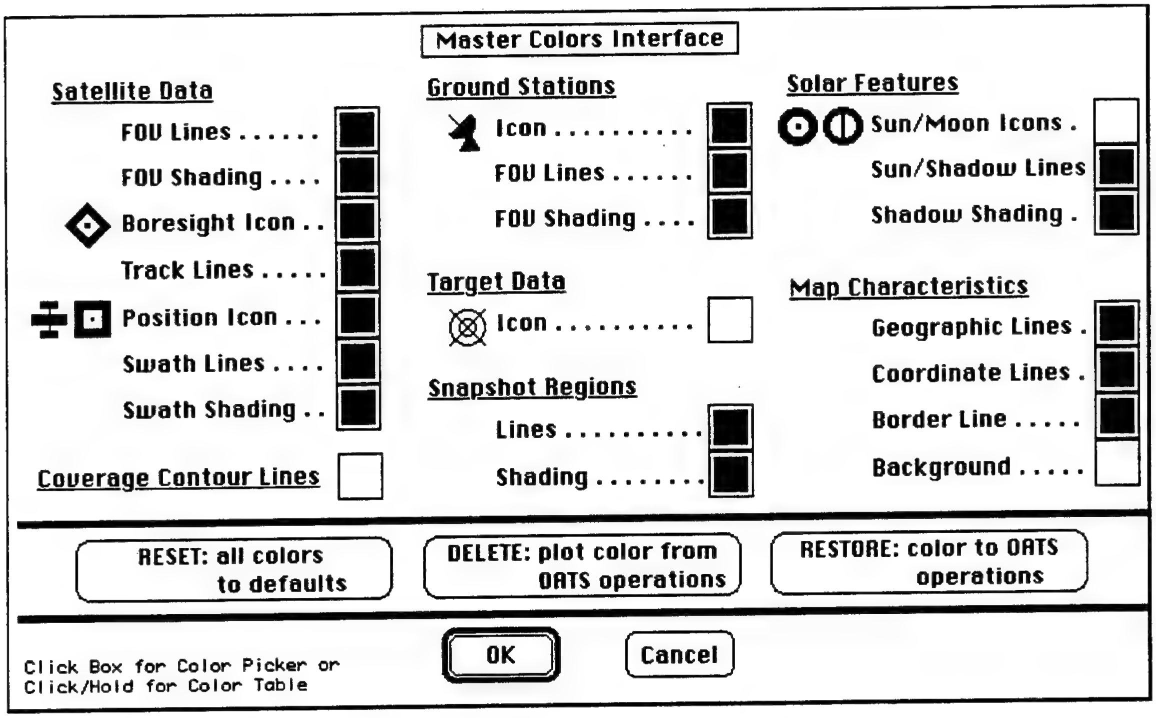


Figure 7-54. Master Colors Interface Dialog

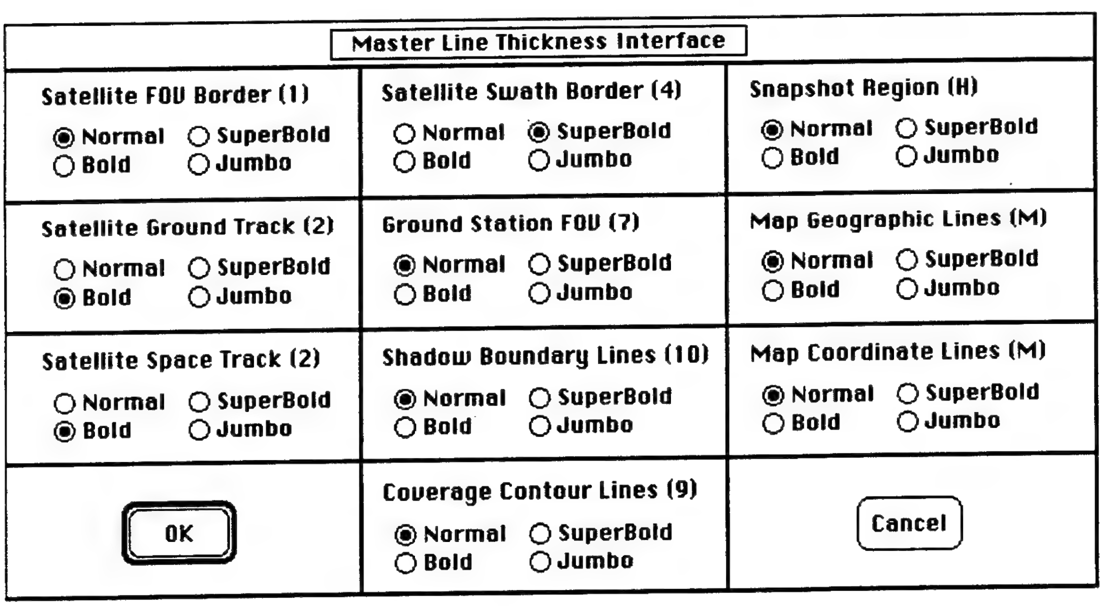


Figure 7-55. Master Line Thickness Interface Dialog

Line Thickness...

As with symbols, all individual plot processes have individual controls that can be used to change the colors of plotted icons, lines, and shaded regions. The **Line Thickness** menu selection displays the dialog shown in Figure 7-55, which provides the user a master control dialog of radio button controls that can be used compare and set all line thickness settings simultaneously. Thickness is set by pixels, where:

- Normal = 1 pixel
- Bold = 2 pixels
- Super Bold = 3 pixels
- Jumbo = 4 pixels

Line Density...

Although lines drawn by OATS will typically be chosen as solid lines, on some occasions it is useful to have lines--especially boundary lines--drawn as a shaded or partial line. Figure 7-56 shows the master interface that allows all line densities to be set and viewed at the same time. Density settings range from 0 through 9, and are set using slide controls. Although it is nearly transparent to the user, there are actually two different types of line densities. Those in the upper group from Figure 7-56 employ lines with a density pattern to make them appear more or less broken. Figure 7-57 provides some examples at 4 pixel line widths of the various settings for line densities, with 0 levels being a solid line. All line densities in the upper group may be turned off by setting them to the maximum value. The *Track* line densities in the lower group are handled differently. They are not completely deleted at maximum value, as an invisible line for tracks is without purpose. Rather than a density pattern, satellite track lines are series of intermittent dashes. The length and density of the dashes are a composite of the line density setting, the step size (in seconds) used to plot the orbit, and the geometry of the map projection. The best way to find the right setting is to experiment.

Shading Density...

Area plots made by OATS (other than continents in maps) are drawn as shaded regions. The dialog shown in Figure 7-58 provides the master interface that allows all shading densities to be set and viewed at the same time. Shading density settings range from 0 through 11, are set using slide controls, and may be set to solid patterns by setting them to the maximum value. Figure 7-59 provides some samples of shading density patterns. As a general rule of thumb, in cases where shaded regions overlap, it is best to use different density settings.

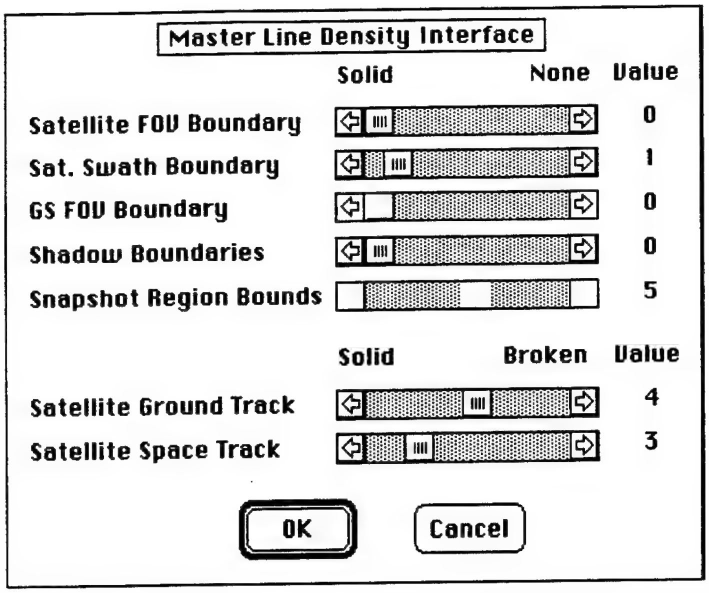


Figure 7-56. Master Line Density Interface Dialog

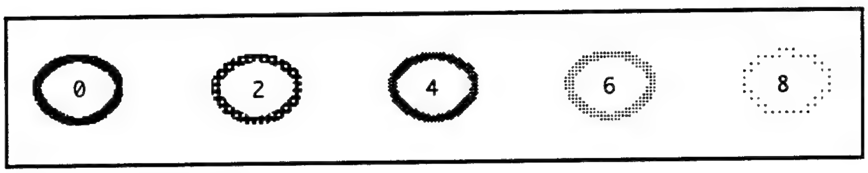


Figure 7-57. Line Density Samples

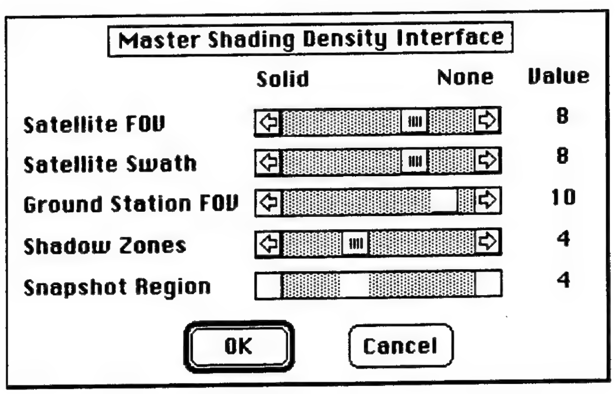


Figure 7-58. Shading Density Interface Dialog

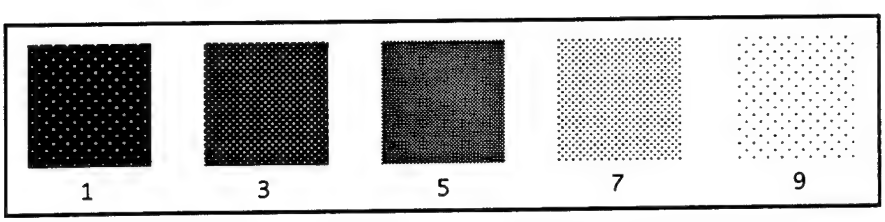


Figure 7-59. Shading Density Samples

7.16 WIPE SCREEN

Wipe Screen eliminates all layers of plotted data in the current work area. Since the current work area is typically the full Graphics Window, this command wipes the screen clear. However, if using some non-typical plotting configuration, it may be necessary to employ the **Clear** command in the **Edit** menu (see Section 5.3) to clear the screen. The **Wipe Screen** command is used to start a fresh plot. It can also be accessed with an **⌘-W** command key.

7.17 UTILITY DIALOGS

This section discusses utility dialogs used in multiple places throughout the **Plot** menu tree. Some of them also appear in other places in the OATS system; however, their primary functionality lies with plotting operations.

7.17.1 COLOR SELECTION

OATS makes extensive use of color in its plotting routines. Figure 7-60 allows the user to set the color employed by line plot functions, area plot functions, and most symbol plot functions. This dialog presents a short title for the information in question, and a small *Color* swatch of the current color setting. The user may reset the color in three ways. The first is to use one of the eight standard QuickDraw colors (Reference 6) using the radio button controls. The second is to use the color look-up table. By clicking and holding the mouse on the swatch, an expanded view of the 256 available colors is presented--one of which can be singled out with the mouse. If this option is used, the color settings retained by OATS will be exactly those of the color selected. The third way is to use the *Color Picker* by simply clicking on the swatch, which presents the standard Macintosh Color Picker Dialog Box (Reference 8). The Picker dialog varies between systems, but usually presents a color wheel, a brightness scroll bar, and numerical color settings that can be used to set any color. The user should note that although the Picker is an easy way to set colors, any color set using the Picker will be rounded to whichever of the 256 colors in the look-up table is closest. If a Picker or table color is selected that matches one of the eight button colors, the appropriate button will be set. As usual, the *Cancel* button will nullify any color settings changed in this dialog and the *Set* button will retain them for OATS plotting functions. All color settings are saved between OATS executions.

7.17.2 FONT SETTINGS

The appearance of plotted text in OATS is controlled with the dialog shown in Figure 7-61. A small set of sample characters is displayed in the right hand window using the current font settings. The *Text Characteristics* pull-down menu can be used to set the font, size, style, and color in standard Macintosh fashion. Note that in some cases the Underline style has been disabled for OATS because that print style can interfere with plot clarity. Again, the *Cancel* button will nullify any settings changed in this dialog and the *OK* button will retain them for OATS plotting functions. All font settings are saved between program executions.

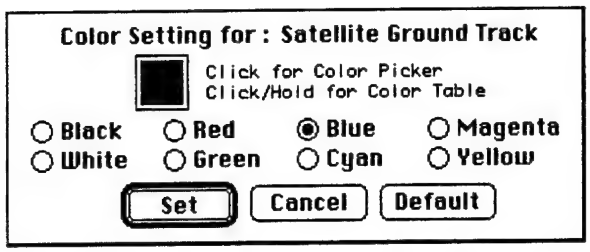


Figure 7-60. Utility Dialog for Color Selection

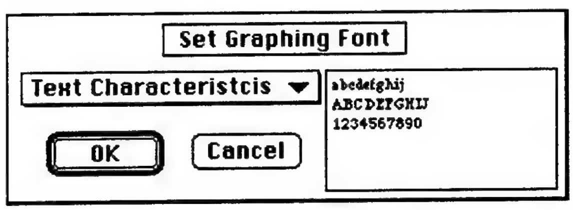


Figure 7-61. Utility Dialog for Font Selection

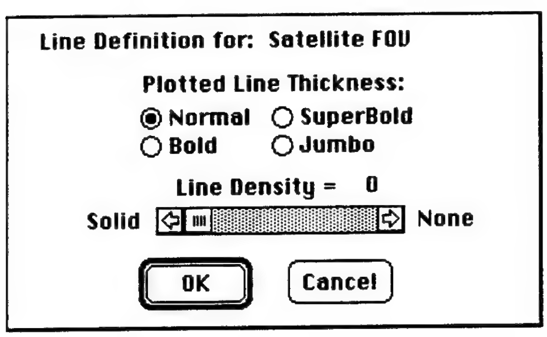


Figure 7-62. Utility Dialog for Line Definition

7.17.3 LINE DEFINITION

Lines that are plotted by OATS, e.g. coordinate lines, swath borders, ground station FOV borders, etc., are usually defined by a *Line Thickness* in pixels and a *Line Density* or transparency. The utility dialog in

Figure 7-62 is used to set most line definitions in the **Plot** menu trees. Thickness is set with radio buttons, and ranges from a *Normal* single-pixel width line to *Jumbo* which has a line width of 4 pixels. A total of 10 levels is available to set line density using the control slide which varies from *Solid* (0) to *None*(9). See section 7.15 for additional discussion.

7.17.4 SHADING DENSITY SELECTION

Regions that are plotted by OATS, e.g. shadow areas, swath coverage, ground station FOV, etc., are defined by a *Shading Density* or transparency. The utility dialog in Figure 7-63 is used to set most shading values in the **Plot** menu trees. A total of 12 levels is available to set shading density using the control slide which varies from *Solid* (0) to *None*(11). See section 7.15 for additional discussion. As a general rule of thumb, in cases where shaded regions overlap, it is best to use different density settings.

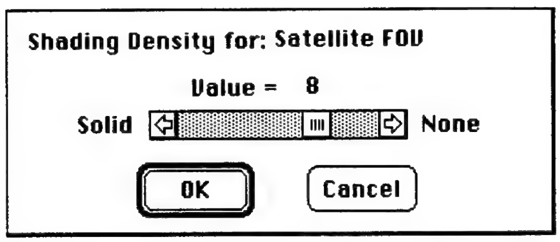


Figure 7-63. Utility Dialog for Shading Density Selection

7.17.5 ANTENNA PARAMETERS

Spacecraft antenna patterns may be quantified using the utility dialog seen in Figure 7-64. The angles *Specification* is accomplished using three radio buttons and a checkbox on the left side of the dialog. The definitions pertinent to these controls are discussed in Appendix A--it is strongly recommended reading before using this dialog. Angle values for the antenna may be specified in the middle *Values* section of the dialog. The *Secondary Angle* is only required and can only be set for the case of a FOV shaped like an *Annulus*. Note that in the example shown, the data is presented in *INPUT MODE*. In some uses of this dialog in OATS, the data is presented in *VIEW MODE* and cannot be changed. To the right of the dialog is a button that allows the user to bring up an *Angle Conversion Computer*--a special small slave dialog seen in Figure 7-65 that is used to compute the *Primary* and *Secondary* angles for the antenna in an alternate geometry. It is useful to be able to visualize the antenna angles in a different format by simply pushing the *Elevation*, *Cone*, or *Earth Central* buttons. Note the dot to the right of the buttons in Figure 7-65 shows the current angle formulation. If Exit is pushed, the computer returns to the Antenna Parameters dialog with no changes. If *Keep Angles* is used as the exit, the most recent choice of angle geometry and the newly displayed angles are retained.

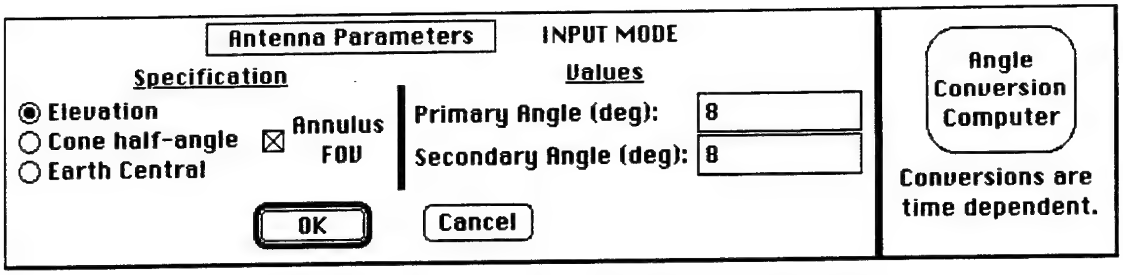


Figure 7-64. Utility Dialog for Antenna Parameter Selection

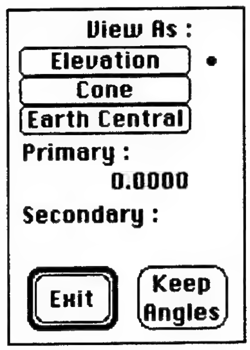


Figure 7-65. Utility Dialog for Angle Conversion Computer

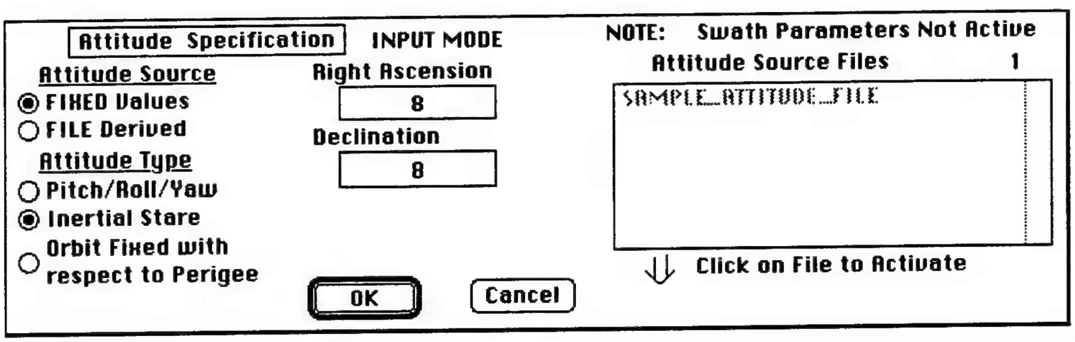


Figure 7-66. Utility Dialog for Attitude Parameter Selection

7.17.6 ATTITUDE PARAMETERS

Spacecraft attitude parameters are important for coverage analysis and for plotting of coverage regions. They are specified in the second level dialog shown in Figure 7-66. Because this is a second level dialog, there is sometimes an informational message displayed in the upper right corner of the dialog. As with the antenna parameters in the previous section, the attitude parameters can be viewed in an *INPUT MODE* as well as a *VIEW MODE*. The *Attitude Source* of data can be specified using radio buttons to choose *FIXED Values* or *FILE Derived* values. If fixed values are selected, the *Attitude Type* may be specified with a choice of three radio buttons. The fixed angles for the three cases are:

Pitch/Roll/Yaw	*Pitch*, *Roll*, and *Yaw* attitude angles
Inertial Star	*Right Ascension* and *Declination* of the stare point
Orbit Fixed w.r.t. Perigee	Unit vectors in the perifocal coordinate system

See Appendix A.2 for precise definitions of these attitude specifications.

If a file derived attitude is elected, attitude files (see Section 10) must first have been opened (see Section 9). Open *Attitude Source Files* are displayed in the list to the right of the dialog. The user may click on the file of interest, which has a self-contained flag that determines the *Attitude Type*.

SECTION 8 - COVERAGE MENU

The OATS program has the ability to perform three types of orbit coverage analysis--tabular coverage, graphical coverage, and look angle coverage. These three computational options are accessed by the **Coverage** menu, shown in Figure 8-1. Each of the types of coverage analysis, **Tabular**, **Graphical**, and **GS Look Angles**, has a sub-menu that offers several choices used to set-up the computational run. After setting the parameters, the specific Run option is used to initiate execution of the coverage computation.

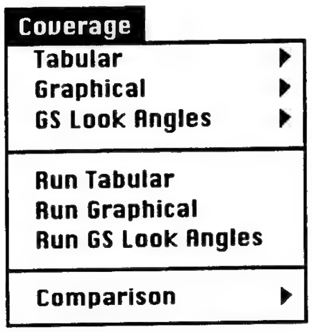


Figure 8-1. **Coverage** Menu

In each of the following sections ground station visibility is defined to occur when the satellite is above some minimum elevation from the ground station horizon. Target visibility is defined to occur when the target lies in the satellite antenna pattern.

8.1 TABULAR COVERAGE

This analytical procedure yields a tabulated list of visibility statistics for a user-defined combination of ground stations, satellites, and targets. Up to 31 ground stations, 27 satellites (synonymous with a maximum 27 separate active ephemeris files), and 100 targets may be used in a single run. The **Tabular** coverage function computes orbital coverage statistics for a system of satellites as viewed by a set of ground targets. A target is said to be covered when exactly n satellites or n-or-more satellites in the system is visible to the target. Any or all of the satellites may optionally have a constraint applied such that any or all of a set of ground stations must be visible for coverage to exist. This is a condition that might apply if a direct satellite communications link is required. The antenna pattern is specified for each satellite individually. The **Tabular** coverage function uses an oblate Earth and can optionally account for atmospheric refraction effects.

8.1.1 PREPARATION MENUS

In order to execute a tabular coverage run, five sets of data must be selected. These include at least one ephemeris file, optional antenna parameters for each file, optional attitude parameters for each file, optional ground stations, and at least one target position. Ephemeris files are selected first using the **Ephemeris** menu (see Section 9) to select and open an active list of files. All open ephemeris files will be used for the tabular coverage run. The remaining sets of data are set using the preparatory sub-menus shown in Figure 8-2.

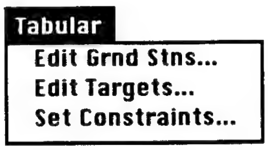


Figure 8-2. **Tabular** Coverage Sub-Menu

Edit Grnd Stns...

This menu selection allows the user to choose the set of ground stations that will be used for the tabular coverage run. It brings up a dialog identical to that shown in Figure 7-21. The function of that dialog is discussed in Section 7.6 and the user is referred there for information on how to fill the active list of ground stations. At least one ground station is required if any of the ephemeris files is associated with a ground station constraint (see below).

Edit Targets...

This menu selection allows the user to choose the set of targets that will be used as part of the tabular coverage run. It brings up a dialog identical to that shown in Figure 7-16. The function of that dialog is discussed in Section 7.5 and the user is referred there for information on how to fill the active list of targets.

Set Constraints...

When each ephemeris file is opened it is assigned a default set of null constraints, including antenna parameters, attitude parameters, ground station constraints, and target constraints. All of these parameters can be changed using the **Set Constraints** menu, which brings up the dialog shown in Figure 8-3. To change any of the constraints, select an ephemeris file from the active list by clicking on the name of a file in the *Ephemeris File List*. The name of the selected file will appear as the *Active Ephemeris File* to verify the file that is in the process of being changed. The *SET ANTENNA Parameters* and *SET ATTITUDE Parameters* buttons bring up the same utility dialogs discussed in Section 7.17.5. Their function is the same as noted for satellite FOV (Section 7.1) and swath (Section 7.4) plotting.

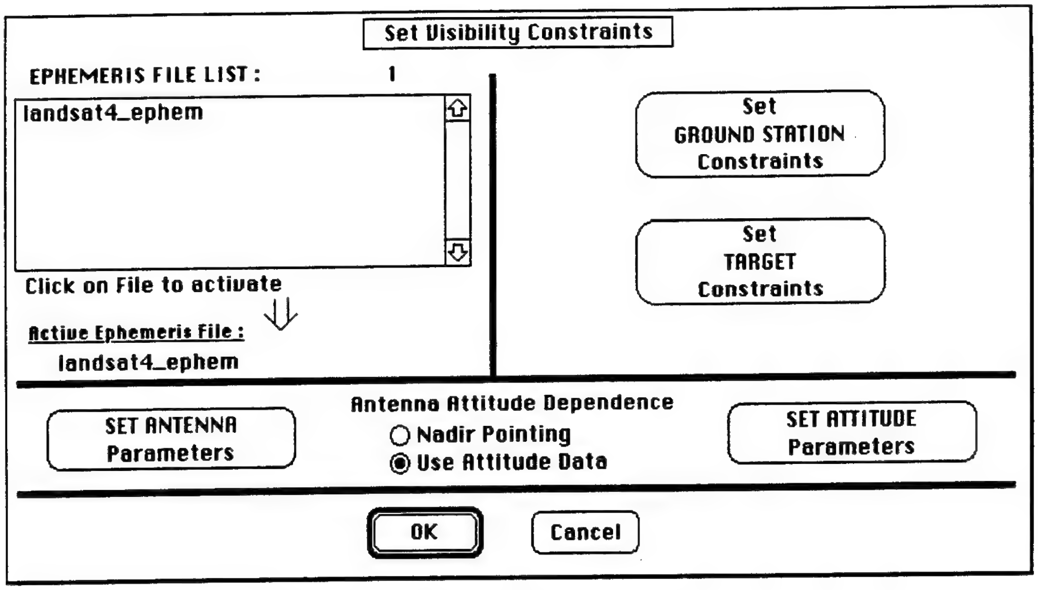


Figure 8-3. Visibility Constraints Dialog

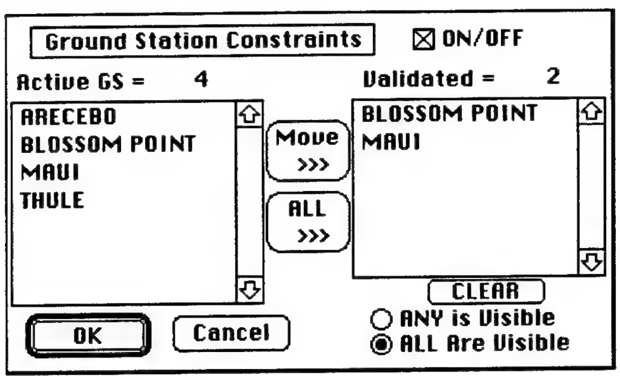


Figure 8-4. Ground Station Constraints Dialog

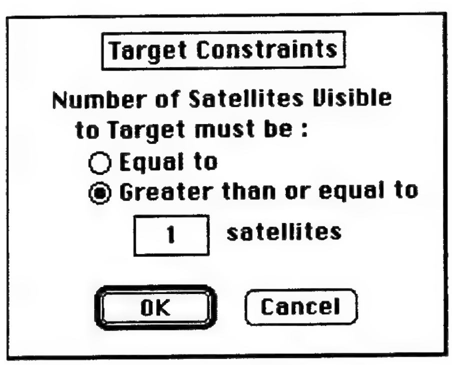


Figure 8-5. Target Constraints Dialog

Selecting *Set GROUND STATION Constraints* shows the dialog seen in Figure 8-4. The fundamental *ON/OFF* switch in this new second-tier dialog serves as the activation switch for ground station constraints for the active file. The user may choose a subset of the *Active* ground

stations to act as constraint factors for the active file. The *ALL* button validates all ground stations, and the *Move* button will validate any contiguous subset from the left-hand list. Radio buttons permit a choice of ANY or ALL of the validated ground stations as a constraining condition. The CLEAR button serves only as an aid in editing the list of validated ground stations. Selecting *Set TARGET Constraints* shows the dialog seen in Figure 8-5. Potential target constraints are rather simple. A user-input number n of visible satellites is linked with a radio button selection of *Equal to* n or *Greater than or equal to* n satellites for the constraining condition. The target visibility by individual satellites is determined by nesting their ground station constraints (if any) simultaneously with the target lying in the antenna pattern.

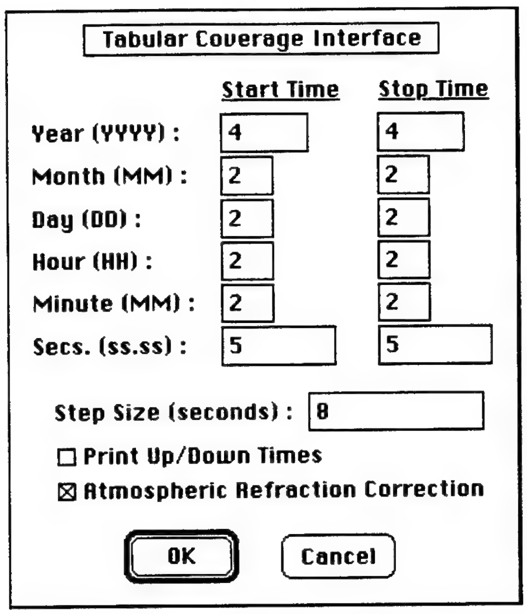


Figure 8-6. Tabular Coverage Dialog

8.1.2 **RUN TABULAR** MENU

When all parameters have been set, a tabular coverage run is initiated by selecting **Run Tabular** from the **Coverage** menu shown in Figure 8-1. The Tabular Coverage Dialog shown in Figure 8-6 will appear. The initial *Start Time* and *Stop Time* will be the minimum and maximum values found in the collected set of ephemeris files. These can be changed, but must be within the bounds of all files used. The step size will be used to set the output computational interval. There is no direct relationship between this interval and the intervals used when creating ephemeris files. An interpolation routine is used to compute satellite state vectors from the available ephemeris data. A checkbox exists in the dialog to allow the option to *Print Up/Down Times* for each coverage period to the output tabular data. A checkbox also exists to allow the *Atmospheric Refractive Correction* to be turned on or off. *Cancel* will return the user to the main menu,

while *OK* will initiate calculation of the tabular coverage. The Macintosh standard file interface will first appear to allow the user to select a file and directory for output of the computed tabular data. If the user wishes to watch the calculations in progress and has set the System Parameters (see Section 5.1) appropriately, a Tabular Window will be opened and will contain an echo of the computed output tabular data. A tabular coverage run may be aborted by the user by pushing and holding the mouse button. Execution will stop, there will be an alert message, and whatever portion of the file of computed tabular data has been generated will be left intact. An example of the output file of tabulated coverage data is shown in Section 11.

8.2 GRAPHICAL COVERAGE

The graphical coverage function computes world-wide coverage of a system of satellites. This process computes the cumulative coverage, average outage, and maximum outage times over a global target grid uniformly spaced in latitude and longitude. Target visibility is defined to occur when one or more satellites has the target in its antenna pattern while its ground station constrint (if any) is simultaneously satisified. The process does not employ n-fold coverage as in the tabular case. It uses the meridian mesh technique of Casten and Gross (Reference 10) for nadir pointing satellites, and a related meridian mesh technique from Middour (Reference 11) for attitude-dependent cases. Coverage statistics are computed at each point in the grid. The technique is quick because a spherical earth is used as a simplifying assumption for the target positions, although an oblate earth model is used for the ground station constraints. Coverage is calculated using geometry only--no atmospheric or aberration effects are included in the model.

By itself, this analysis function does not produce coverage information that is of direct value to most users. Rather, it serves as a set-up procedure that yields a single file of tabulated coverage data that can be employed by the **Plot** menu options (see Sections 7.8 and 7.9) to produce a graphic contour or density mapping of satellite coverage. This mapping is usually shown superimposed on an earth plot to show the extent of coverage for a given satellite grouping. Both dimensions of the global latitude/longitude mesh size can be specified by the user. An increment as small as 1.0 degree can be used; however, the smaller the mesh the longer the compute time. The mesh effectively takes the place of the individual targets used in the tabular coverage procedures discussed above. Exactly as with tabular coverage, any or all of the satellites may optionally have a constraint applied such that at least one ground station must be visible for coverage to exist. Again, up to 31 ground stations and 27 satellite ephemeris files may also be used as simultaneous inputs to the graphical coverage analysis.

8.2.1 PREPARATION MENUS

In order to execute a graphical coverage run, five sets of data must be selected. These include at least one ephemeris file, optional antenna parameters for each file, optional attitude parameters for each file, optional ground stations, and the latitude and longitude spacing of the global mesh elements. Ephemeris files are selected first using the **Ephemeris** menu (see Section 9) to select and open an active list of files. The remaining sets of data are set using the preparatory sub-menus shown in Figure 8-7.

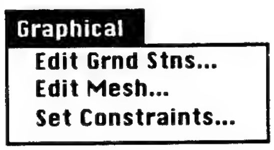


Figure 8-7. **Graphical** Coverage Sub-Menu

Edit Grnd Stns...

This menu selection allows the user to choose the set of ground stations that will be used as satellite visibility constraints for the graphical coverage run. It brings up a dialog identical to that shown in Figure 7-21. The function of that dialog is discussed in Section 7.6 and the user is referred there for information on how to fill the active list of ground stations. At least one ground station is required if any of the ephemeris files is associated with a ground station constraint.

Edit Mesh...

This menu selection allows the user to set the latitude and longitude spacing of the global mesh elements. It brings up the dialog shown in Figure 8-8. Mesh dimensions must be entered as integer values greater than or equal to 1 degree. The mesh need not be "square" (i.e. equal valued).

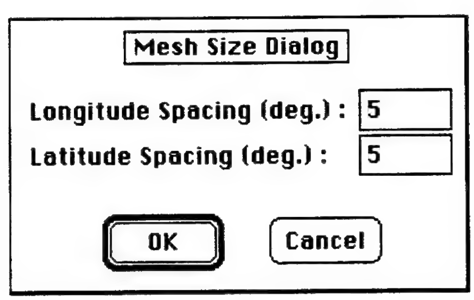


Figure 8-8. Mesh Size Dialog

Set Constraints...

This menu selection allows the user to choose the constraints that define the visibility pattern for each satellite. It brings up a dialog identical to that shown in Figure 8-3, and discussed in Section 8.1.1. The user is referred there for information on how to set the visibility constraints. Note that

only the target constraint options will be inactive, as they do not apply to graphical coverage computations, i.e. the computation is fixed at 1-fold or greater coverage.

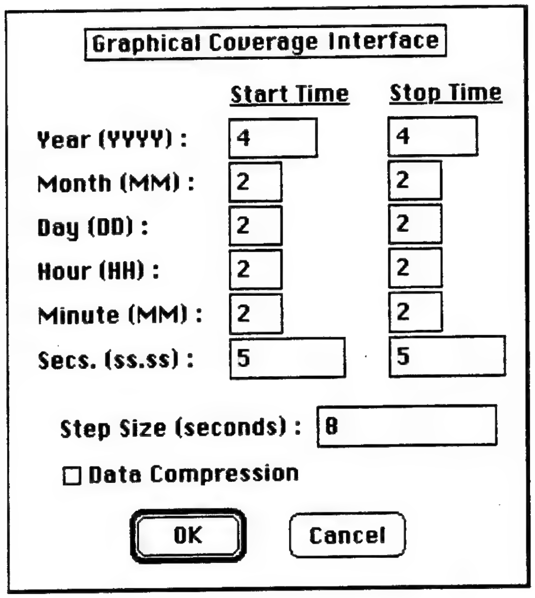
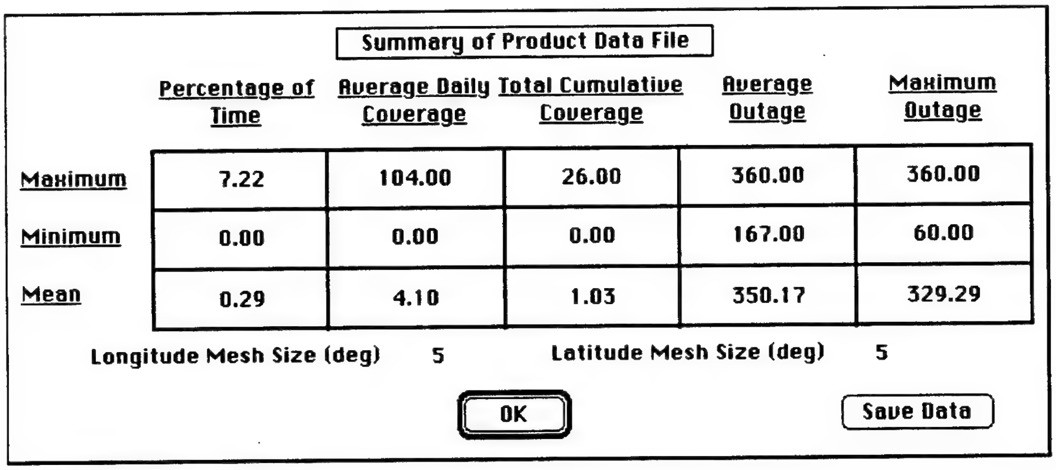


Figure 8-9. Graphical Coverage Dialog

8.2.2 **RUN GRAPHICAL** MENU

When all parameters have been set, a graphical coverage run is initiated by selecting **Run Graphical** from the **Coverage** menu shown in Figure 8-1. The Graphical Coverage Dialog shown in Figure 8-9 will appear. The initial *Start Time* and *Stop Time* will be the minimum and maximum values found in the collected set of ephemeris files. The step size is used to set the computational interval. Again, there is no direct relationship between this interval and the intervals used when compiling the ephemeris files. A checkbox exists in the dialog to allow the option to turn *Data Compression* of the output file on or off. A discussion of compression and of how the data in the output file is mapped onto the global grid is provided in Section 10.7. *Cancel* will return the user to the main menu, while *OK* will initiate calculation of the file required to make coverage plots. The Macintosh standard file interface will first appear to allow the user to select a file and directory for output of the computed data. If the user decides to terminate generation of the coverage run, the mouse button can be pressed and held. An alert message notifying the user of the aborted run will be displayed, and any portion of the generated file will be deleted. If the user wishes to watch the calculations in progress and has set the System Parameters (see Section 5.1) appropriately, a Tabular Window will be opened and will contain an echo of the computed output data; however, you are cautioned that these computations can be time consuming. If the user has elected to have a progress display (see **System Params** under Section 5.1), a graphic will be presented like that seen in Figure 6-16 showing a fill-bar graphic of progress toward completion. As the preparation of the graphical coverage tabular file is

a two stage process, the progress graphic will be presented twice. This graphic can be valuable in cases where a very small mesh and/or large ephemeris intervals result in lengthy wait periods. If the user suspects there is a problem with the initial conditions, the file generation process can be aborted by hitting the button in the progress display. If elected in the **System Params** settings, upon completion of generation of the graphics coverage set-up file, a summary of the data it contains similar to that shown in Figure 8-10 is displayed. This display demands no user inputs--it exists only to give the user some concept of the values that should be looked for when exercising the **Plot** menu options. There is a single *Save Data* button that will save the summary data to a user-selected file via the Macintosh standard file interface.



Summary of Product Data File

	Percentage of Time	Average Daily Coverage	Total Cumulative Coverage	Average Outage	Maximum Outage
Maximum	7.22	104.00	26.00	360.00	360.00
Minimum	0.00	0.00	0.00	167.00	60.00
Mean	0.29	4.10	1.03	350.17	329.29

Longitude Mesh Size (deg) 5 Latitude Mesh Size (deg) 5

OK Save Data

Figure 8-10. Graphical Coverage Summary Display

8.3 LOOK ANGLE COVERAGE

Look Angle coverage is used to produce a tabular list of data that describe where and when a single ground station will be able to view a single satellite as it passes overhead. The listing includes readouts of time vs. azimuth, elevation, range, range rate information, shadow status, and signal attenuation. Calculations for the look angles solutions use an oblate earth, atmospheric refraction, aberration, and a Hopfield model for the tropospheric refraction effect on signal transmission through the Earth's atmosphere (Reference 12) that results in an equivalent propagation delay .

8.3.1 PREPARATION MENUS

In order to execute a look angles coverage run, three inputs must be selected. These include a single ground station, a single satellite ephemeris, and the up-link and down-link communication frequencies. At least one ephemeris file must first be selected and opened using the **Ephemeris** menu (see Section 9). The remaining data selections are performed using the preparatory sub-menus shown in Figure 8-11.

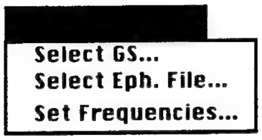


Figure 8-11. **GS Look Angles** Coverage Sub-Menu

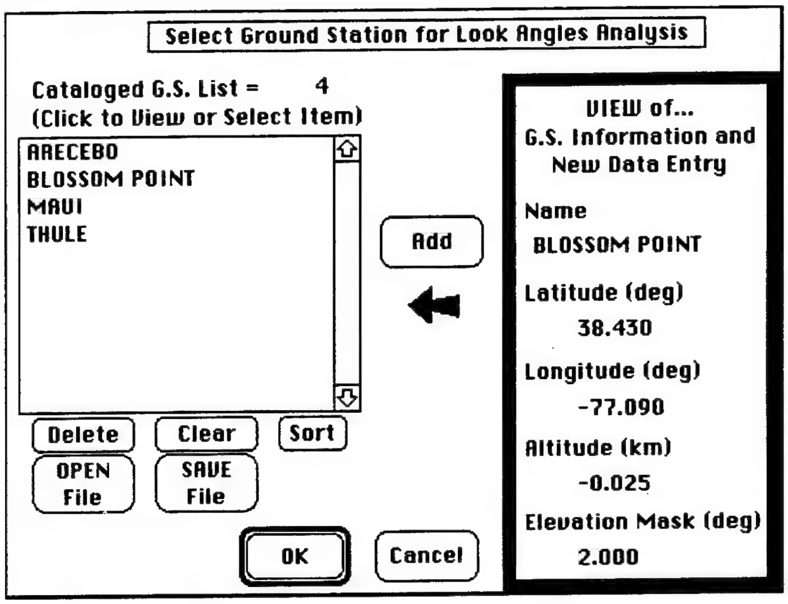


Figure 8-12. Look Angles Ground Station Selection Dialog

Select GS...

This menu selection allows the user to choose the ground station that will be used for the look angles coverage run. It brings up the dialog shown in Figure 8-12. Note that this dialog is similar in many ways to the ground station interface described in Section 7.6; however, it is geared to a situation where a single ground station rather than a set must be identified. The ground station for look angle computations is selected from the *Cataloged Ground Station List*, which is maintained between executions of OATS. This is the same cataloged list used in the **Plot** menu as a source of ground stations for plotting. To select and activate the one required ground station from the list, click on the ground station name. The station information (*Name*, *Latitude*, *Longitude*, *Altitude*, and *Elevation Mask*) will appear in the *VIEW* information box. The cataloged list can be edited using the *Clear* button to erase all entries, the *Delete* button to delete a contiguous set of entries that the user has highlighted, or the *Sort* button to do an alphanumeric sort of the list elements. Entries can be added by manually typing data into each of five *VIEW* boxes and clicking the *Add* button. A new cataloged list can also be retrieved from a previously saved file of ground stations (see Section 7) using the *OPEN File* button. A mouse click here will bring up the standard Macintosh file interface, which can be used to locate and select a file of ground stations. Similarly, the *SAVE File* button can be used to save a copy of the list to a file. *Cancel* will as

usual return the cataloged list and the active ground station to their status before the dialog was entered.

Select Eph. File...

This menu selection allows the user to choose the satellite ephemeris file to be used for look angle processing. It brings up the dialog shown in Figure 8-13. If no files appear in the list, no files are open and the user must visit the **Ephemeris** menu (see Section 9). To designate the file you want to use for a look angles run, highlight the file name with a mouse click and exit with *OK*. Alternatively, a double click on a file will select the file and close the dialog.

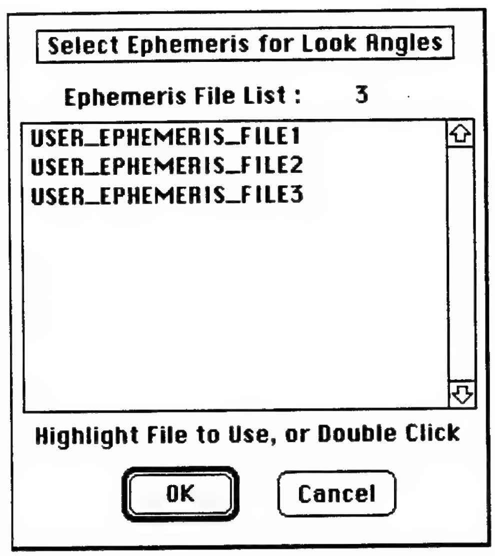


Figure 8-13. Look Angles Ephemeris File Dialog

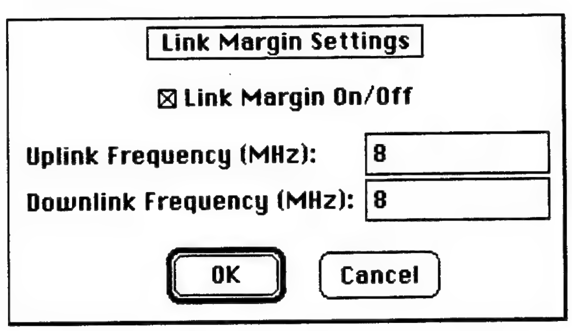


Figure 8-14. Link Margin Settings Dialog

Set Frequencies...

Figure 8-14 shows the menu which appears after this menu selection. It allows the user to choose the up-link and down-link frequencies (in megahertz) used to compute signal attenuation. A switch is also available to turn this computation on or off, which will shorten the computation time

and the printout format. The mathematical formulation of the link margin computations can be found in Reference 13.

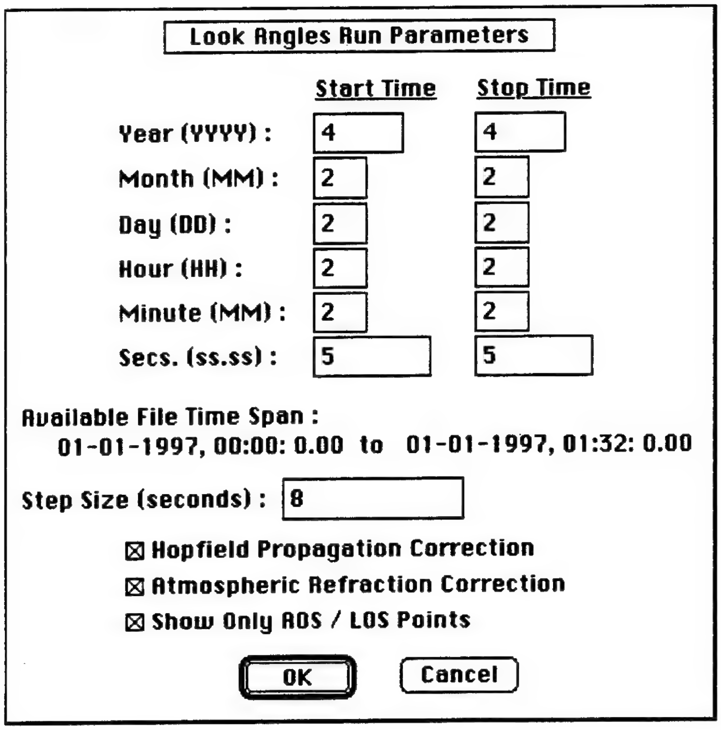


Figure 8-15. Look Angles Dialog

8.3.2 **RUN GS LOOK ANGLES** MENU

When all parameters have been set, a look angles coverage run is initiated by selecting **Run GS Look Angles** from the **Coverage** menu shown in Figure 8-1. The Look Angles Run Parameters Dialog shown in Figure 8-15 will appear. The initial *Start Time* and *Stop Time* will be the minimum and maximum values found in the chosen ephemeris file. These may be modified, but the coverage interval must be within the bounds of the file. The full interval of this file is shown in the *File Time Span* field in case the user requires adjustments. If the *Start Time* or *Stop Time* is adjusted, be sure the new times still fall within the times in the selected ephemeris file. The step size will be used to set the computational interval. Again, there is no direct relationship between this interval and the interval used when creating the ephemeris file. Checkboxes exist in the dialog to allow the *Hopfield Propagation Correction* , *Atmospheric Refraction Correction,* and *Only AOS/LOS Points* options to be turned on or off. *Cancel* will return the user to the main menu, while *OK* will initiate calculation of look angle coverage. The Macintosh standard file interface will first appear to allow the user to select a file and directory for output of the computed look angles data. If selected under the System Parameter settings (see Section 5), a tabular window will be opened and an echo of the look angle computations will be shown on screen. A look angles coverage run

may be aborted by the user by pushing and holding the mouse button. Execution will stop, there will be an alert message, and whatever portion of the file of computed look angles data has been generated will be left intact. An example of the output file of look angles coverage data is shown in Section 11.

8.4 COMPARISON

One of the newest tools in the OATS system is the ability to run comparisons of graphical coverage files. This is in effect a limited special-purpose type of image processing. As seen from the **Comparison** menu in Figure 8-16, it is possible to perform the difference between graphical coverage files, the sum of multiple files, or the mean of multiple files. It is of course a necessity that the graphical coverage files be generated prior to exercising these options and that they be generated using the same size coordinate mesh.

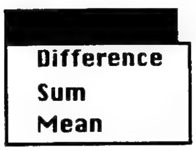


Figure 8-16. **Comparison** Menu

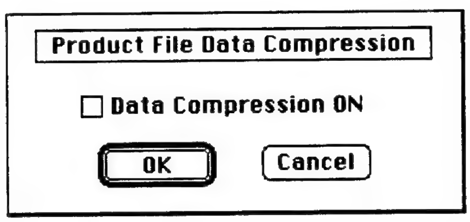


Figure 8-17. Comparison Compression Dialog

Difference

This menu selection allows the user to subtract one graphical coverage file from another. On activation, the user must first identify the *Base* file using the Macintosh standard file interface and then the *Comparison* file. The dialog in Figure 8-17 is then used to inquire if the user wants the output file to be in compressed format--accomplished with a simple checkbox switch. The standard file interface then appears to allow the user to select a destination file and directory for the product comparison file. The OATS progress display will show (if set under **System Params)** the progress to completion. When the output file is complete, it may be displayed using the **Plot** menu (see Section 7). The new file will show a graphical display of (*Base-Comparison*) file data.

Sum

This menu selection functions in an identical fashion to the Difference menu, except that it displays (*Base+Comparison*) file data.

Mean

The largest difference between averaging files and simple sums or differences is that up to nine files may be averaged, rather than just a comparison of two. When the *Base* file identification is requested, the user should understand that this is the same as *Average File #1*. The user will then be asked to identify *Average File #2*. Data is processed to a temporary file. The program then enters into a loop using the dialog seen in Figure 8-18 to find out if additional files should be averaged into the final product graphical coverage file. When the user terminates the loop, the compression dialog and standard file interface dialogs again appear to define the output file.

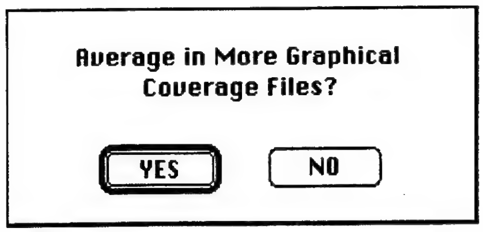


Figure 8-18. Comparison Add-to-Average Dialog

SECTION 9 - DATA MENU

One of the cornerstones of operating OATS involves the use of files to supply time-dependent data--specifically those files used to provide time dependent ephemeris and attitude data. The **Data** menu, shown in Figure 9-1 provides interfaces that allow the user to open files for plotting and coverage analysis activities, to inspect files prior to opening them for analysis, and to use the files to make spot checks of position and attitude based on the file data.

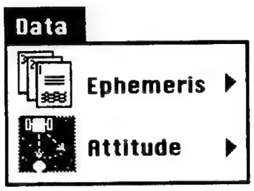


Figure 9-1. **Data** Menu

9.1 EPHEMERIS OPERATIONS

Choosing the **Ephemeris** menu produces the sub-menu shown in Figure 9-2, which allows the user to **Open Files, Inspect Files**, or do a **Position Check**. Details of these three menu choices are described below.

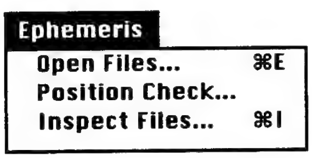


Figure 9-2. **Ephemeris** Menu

Open Files...

OATS operates with two lists of ephemeris files. This is reflected in Figure 9-3, which shows the dialog produced by selection of **Open Files**. The *Cataloged Files* list on the left is composed of files identified by the user which are of potential interest during this execution of OATS. The program retains knowledge of the location of these files for the duration of the current program execution, although none of them are formally opened. There is no specified limit to the number of files that can exist in this list. The other list of *Files Selected to be Opened* holds the "active files". These files are formally opened upon termination of this dialog via the *Open* button. This active list can contain up to 27 files, and is made available to the user at numerous dialogs throughout the **Plot** and **Coverage** menu systems. File location information for both lists is lost upon program termination. If the user temporarily switches out of OATS to some other program (e.g. Finder) and executes a command that affects the location of an identified file (e.g. move it to another directory), OATS will not notice there is a problem until you attempt to *Open*

the active files list. Likewise, files which do not have a valid ephemeris format can be manipulated and selected with this interface dialog without notice of the problem until an *Open* is attempted.

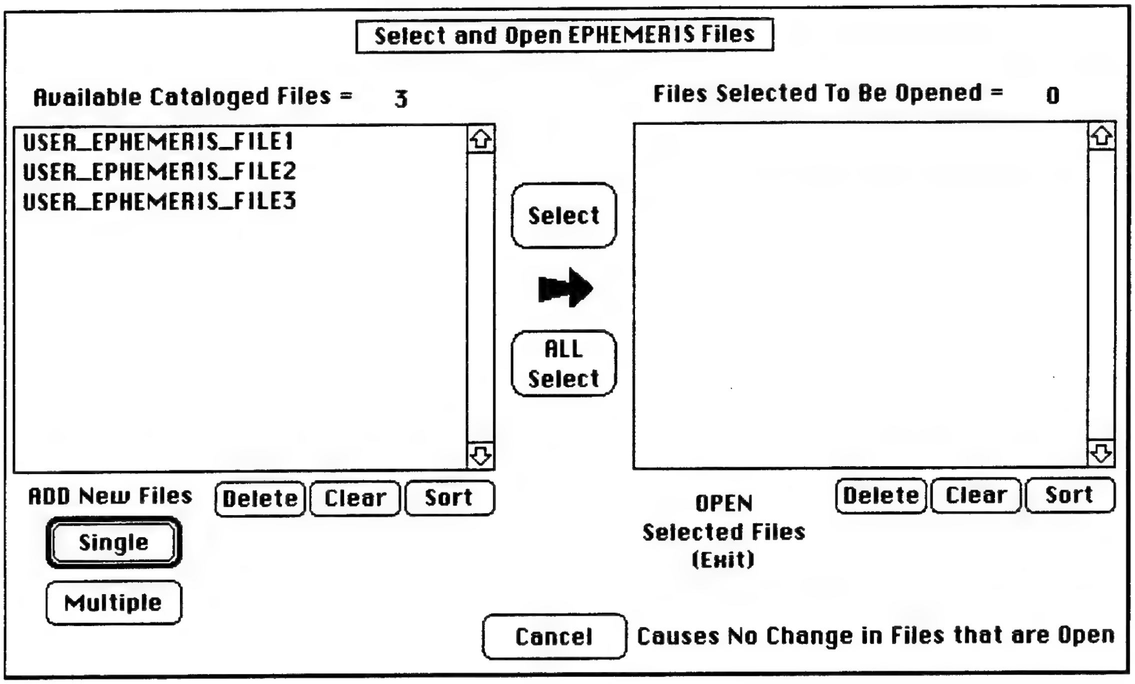


Figure 9-3. Open Files Dialog

Both lists in Figure 9-3 have their respective *Clear* button, which removes all files from that list. Both lists also have their respective *Delete* button which will delete any contiguous highlighted subset of the list with a mouse click. A *Sort* button is available to perform an alphanumeric sort of the files, a sort which does not affect the knowledge base of file locations. *Cancel* will exit the dialog and return both lists to their states prior to entry of the **Open Files** dialog. The *Single* button is the default control button for this dialog. Clicking *New* will bring up the Macintosh standard file interface, which permits the user to select a single file located in any directory. From the standard interface, clicking *SELECT* will add the highlighted file to both the cataloged and active lists. If it is known that multiple files should be opened, the *Multiple* button will access the standard file interface in a loop until *Cancel* is pressed. If a contiguous subset of files is highlighted in the cataloged list then the *Select* button will copy that file into the active list, but nothing is moved if files are not highlighted. The *All* button moves all cataloged files into the active list. As noted in Section 6, there is another way for files to be entered onto the active list--new ephemeris files generated by OATS are automatically entered onto the active list and opened.

Normal use of the **Open Files** dialog interface involves repetitive use of the *Single, Multiple, Delete, Sort, Clear*, and *Select* functions until the desired list of files is achieved in the active list, whereupon the *Open* button is used to exit the dialog. This act opens the files and accesses the defining limits of the selected files, processes which are transparent to the user. Ephemeris files can be imported from other applications, used by OATS, and activated via this interface provided they adhere to certain formatting restrictions. File format is reviewed in Section 10.2. The user will note that files generated by OATS are processed more quickly through this interface because they have header data containing the file's limits. **Open Files** can also be selected by using the **⌘-E** command-key.

Position Check...

This option provides a calculation of satellite position accurately interpolated from the satellite ephemeris file. For any open ephemeris file, and within the temporal bounds of that file, the interface shown in Figure 9-4 provides a means of computing the satellite position with the flick of a single button. All open ephemeris files are displayed in the *EPHEMERIS FILE LIST.* Clicking on one of these files makes it *Active*, and displays the *Time Span* over which positions are available. The user enters a *Time* in the appropriate spaces in the upper right corner of the display, and presses *SHOW Position. Latitude, Longitude, Altitude*, and *Hour Angle* are computed and displayed in the box at the bottom of the display. This can be repeated as often as desired. *EXIT* terminates the computations and leaves the interface.

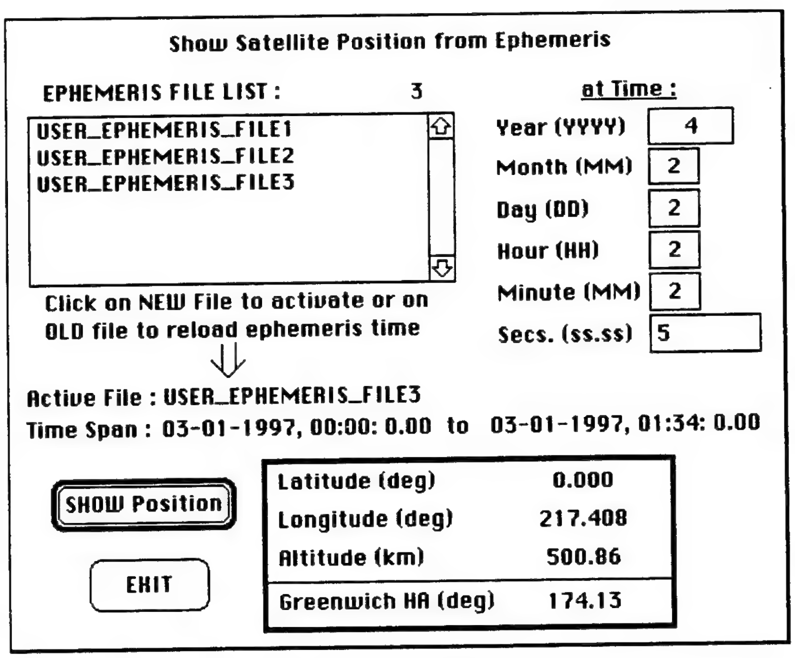


Figure 9-4. Position Check Interface

Inspect Files...

The **Inspect Files** menu option is designed to allow the user to preview ephemeris file data prior to including it in the cataloged or active lists. Selection of **Inspect Files** from the menu or using the **⌘-I** command-key will bring up the dialog seen in Figure 9-5, but with all file descriptive fields empty. The *SELECT File* button activates the Macintosh standard file interface, which allows the user to select a file for preview from any directory. Any file thus selected will have its name displayed under *File Name*. If a file has been generated by OATS, it will possess header information that summarizes the file contents (see Section 10.2). All data fields shown in Figure 9-5 will then be displayed. If the file is not an OATS standard format file, then a warning will be generated and the only valid information will again be the *File Name*. After a file is selected, the *View Orbital Elements* button will display a dialog similar to those seen in Figures 6-3 through 6-8 that are used to display orbital element data. These interfaces will be in a VIEW-only mode, allowing no changes or further file interactions. The *End* button in the **Inspect Files** dialog returns the user to the main program menu. The *Add to Active File List* will add a file selected for preview to the active files list and open that file. Once added to the list, there is no way to preview the file's data short of returning to the **Open Files** dialog and deleting the file from the active list. This is due to the fact that only one part of the program may access a file at any given time in the OATS Macintosh environment.

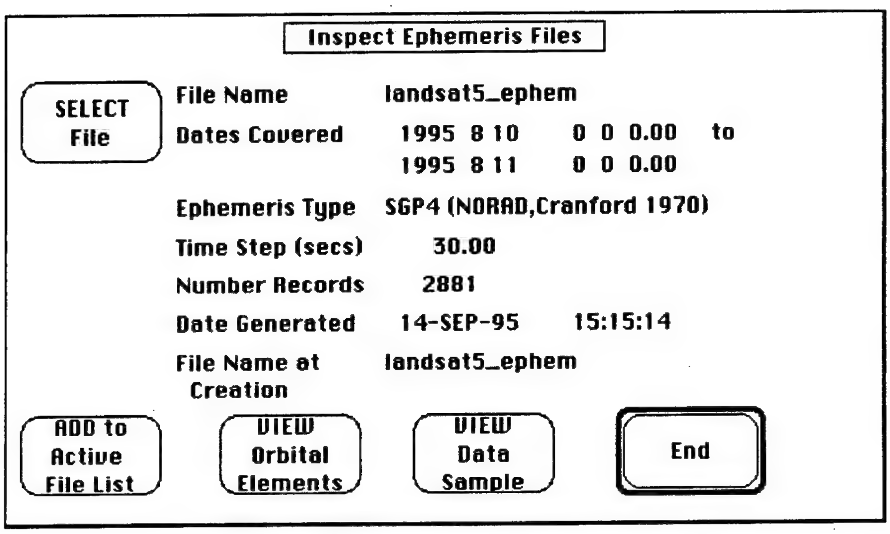


Figure 9-5. Inspect Ephemeris Files Dialog

Whether or not the file is OATS standard format, the *View Data Sample* button can be used to directly preview the data. OATS standard ephemeris file format employs ASCII character data so that the files can be viewed. *View Data Sample* activates the a Text Entry window (see Section 3) as shown in Figure 9-6, displaying the file data in a read-only setting. Note that all file data, including the header data, can be seen.

In-window controls include a grow box in the upper right title bar, the scroll bar controls along the bottom and right sides of the window, and a size box in the lower right corner. A pull down menu under *Text Style* provides limited control over text display, in that it allows 6, 9, or 12 point font to be selected for the display. Line numbers within the file and character numbers within a line can be viewed by locating the cursor and then clicking and holding the mouse key. Locations are displayed in the window title bar as long as the mouse is held. RETURN closes the text display window and returns to the interface shown in Figure 9-5.

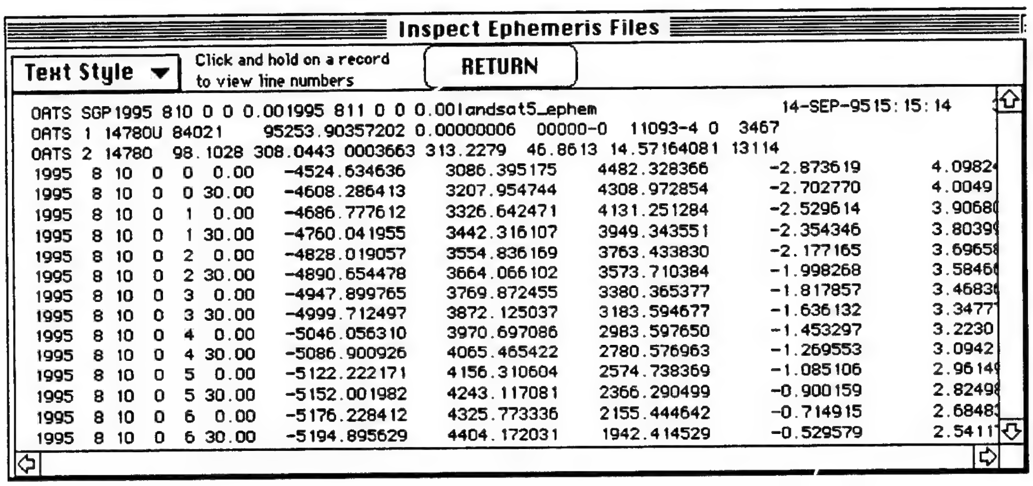


Figure 9-6. Inspect Ephemeris Files View Window

9.2 <u>ATTITUDE OPERATIONS</u>

Choosing the **Attitude** menu produces the sub-menu shown in Figure 9-2, which allows the user to **Open Files, Inspect Files**, or do a **Pointing Check**. Details of these three menu choices are described below.

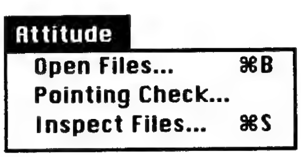


Figure 9-7. **Attitude** Menu

Open Files...

This option for attitude files functions in almost the exact same manner as for ephemeris files as discussed in Section 9.1. The internal lists used to store file location data are different for attitude files. Although there could easily be a one-to-one correspondence between the user's attitude and ephemeris files, there is no direct connection of them that is maintained in the software. Any association is manually established by the user when setting attitude parameters for the swath or

FOV plotting functions (see Sections 7.1 or 7.4) or when setting tabular coverage constraints (see Section 8.1).

Pointing Check...

This option provides a calculation of satellite pointing accurately interpolated from the satellite attitude file. For any open attitude file, and within the temporal bounds of that file, the interface shown in Figure 9-8 provides a means of computing the satellite attitude in a fashion very analogous to that used for positions in the previous section. All open attitude files are displayed in the *ATTITUDE FILE LIST*. Clicking on one of these files makes it *Active*, and displays the *Time Span* over which attitude data are available. The user enters a *Time* in the appropriate spaces in the upper right corner of the display, and presses *SHOW Attitude Angles*. The angles computed depend on the format of the file (see Section 10 or Section 7.17). This process can be repeated as often as desired. *EXIT* terminates the computations and leaves the interface.

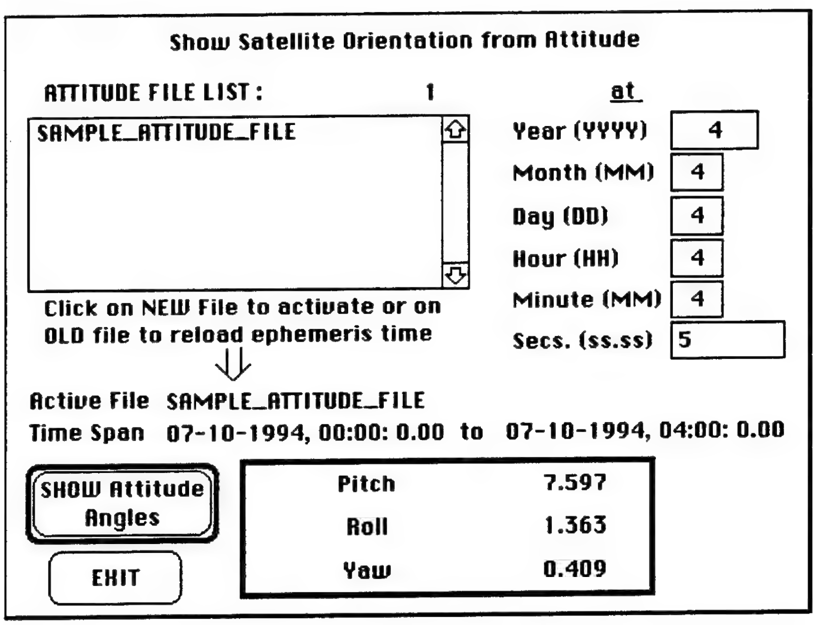


Figure 9-8. Pointing Check Interface

Inspect Files...

The **Inspect Files** menu option functions in a somewhat similar manner as for ephemeris files as discussed in Section 9.1. The difference is that the only capability available is the function that does a direct inspection of the attitude text file. There is no interface like that shown in Figure 9-5--rather the Macintosh standard file interface is opened directly so that an attitude file may be identified. An inspection dialog similar in appearance and function to Figure 9-6 is accessed.

SECTION 10 - FILE FORMATS

This section provides a list and description of all of the files used by OATS the user may wish to directly interact with. A number of scratch files are used by the program; however, these are temporary and will never be seen except in the unusual circumstance that there is an abnormal end to program execution that prevents OATS from closing and deleting these files. Unless specifically stated otherwise, all files are ASCII format with sequential access. All can be created using OATS to write the file; however, they may also be created manually from a text editor or by another computer program.

10.1 ORBITAL ELEMENTS

Four different orbit propagation models are used in Version 5.0 of OATS; PPT2 (Brouwer-Lyddane), RUK12 (4^{th} order Runge-Kutta numerical integration), J2 (first order J_2 analytic), and SGP4 (USSPACECOM formulation of Brouwer solution with drag modeling). Each of the four models requires a different input vector file format, with a total of six possible types of input formats for OATS. The RUK12 and J2 input file formats are non-specific and can be defined by any program utilizing such orbital element sets; however, the PPT2 and SGP4 have very specific native formats which are used to store and transmit element sets. The PPT2 orbit model uses NAVSPASUR One-Line Element Sets (OLES) which come in three varieties: PME, Charlie, and Z formats. The SGP4 model uses Two-Line Element Sets (TLES). Any of these six types of orbital element input files may be created by the user with any text editing program, imported from an external source, or created by OATS using the *Save* buttons in the orbital element data entry dialogs (see Section 6.3.2). Figure 10-1 presents a tested functional example of each of the six types of orbital element files, and the following sections discuss the formats individually.

10.1.1 CHARLIE OLES

The Charlie format is valid at 0 hours Zulu. The OLES in Charlie format is 65 characters in length, with the specific native format and the parameters making up the NAVSPASUR Charlie format one-line element set as follows:

```
IIIII.AAAAAAA.MMMMMMM.DDDDD.EEEEEEE.WWWWWWW.NNNNNNN.IIIIIIIYYMMDD
```

where,

- **IIIII** = satellite SDC number
- **AAAAAAA** = mean anomaly, fraction of a revolution
- **MMMMMMM** = mean motion, radians/herg

DDDDD = decay, radians/herg/herg

EEEEEEE = eccentricity

WWWWWWW = argument of perigee, fraction of a revolution

NNNNNNN = longitude of ascending node, fraction of a revolution

IIIIIII = angle of inclination, fraction of a revolution

YYMMDD = year / month / day

10.1.2 Z OLES

The Z format is also valid at 0 hours Zulu. The OLES in Z format is 69 characters in length, with the specific native format and the parameters making up the NAVSPASUR Z format one-line element set as follows:

IIIIIRRRRRAAAAAAAAMMMMMMMMDDDDDEEEEEEEEWWWWWWWWNNNNNNNNIIIIIIIIYYMMDD

where,

IIIII = satellite SDC number

RRRRR = revolution number

AAAAAAAA = mean anomaly, fraction of a revolution

MMMMMMMM = mean motion, radians/herg

DDDDD = decay, radians/herg/herg

EEEEEEEE = eccentricity

WWWWWWWW = argument of perigee, fraction of a revolution

NNNNNNNN = longitude of ascending node, fraction of a revolution

IIIIIIII = angle of inclination, fraction of a revolution

YYMMDD = year / month / day

10.1.3 PME OLES

The epoch of the PME format one-line element set is more generalized than the other two OLES formats, because space is allocated to specify the epoch to the nearest ten minutes; however, only the last digit of the year can be specified. This makes the decade during which the OLES is valid ambiguous under some circumstances. The OLES in PME format is 69 characters in length, with the specific native format and the parameters making up the NAVSPASUR PME format one-line element set as follows:

IIVRRRRRAAAAAAAAMMMMMMMMDDDDDEEEEEEEEWWWWWWWWNNNNNNNNIIIIIIIIYMMDDHHM

where,

II	= satellite SDC number
V	= version number
RRRRR	= revolution number
AAAAAAAA	= mean anomaly, fraction of a revolution
MMMMMMMM	= mean motion, radians/herg
DDDDD	= decay, radians/herg/herg
EEEEEEEE	= eccentricity
WWWWWWWW	= argument of perigee, fraction of a revolution
NNNNNNNN	= longitude of ascending node, fraction of a revolution
IIIIIIII	= angle of inclination, fraction of a revolution
YMMDDHHM	= year / month / day / hours / tens of minutes

10.1.4 TLES

The two-line element set contains two lines, each of which is 69 characters in length. The specific native format and parameters making up the USSPACECOM TLES format two-line element sets used in OATS are as follows. If a data field is not specifically called out in the explanation, then the TLES must match that field exactly as shown. Some of the data fields, e.g. international designator, are typically shorter than the maximal field size shown. Note that the satellite number is shown as an integer. The overwhelming majority of uses of this field do show it as a number; however, in some rare cases non-numeric fields have been seen in the literature. OATS is capable of treating this as an alphanumeric field, even though it is probably safest for users to continue to think of it and treat it as a number.

```
1 nnnnnU YYLLL  A YYDDD.DDDDDDDD 0.XXXXXXXX  ZZZZZ-J  GGGGG-K T  SSSS
2 nnnnn III.IIII NNN.NNNN EEEEEEE WWW.WWWW AAA.AAAA MM.MMMMMMMM RRRRR
```

where in the first line,

nnnnn	= satellite SDC number
YY	= year of launch
LLL	= launch number of the year
AAA	= international designator (piece of the launch for multi-payload launches)
YY	= last two digits of epoch year
DDD.DDDDDDDD	= epoch, as day and fractional part of day
0.XXXXXXXX	= first time derivative of the mean motion

ZZZZZ	= second time derivative of the mean motion
J	= exponent of second derivative of mean motion
GGGGG	= drag coefficient for SGP4 theory
K	= exponent of drag coefficient
T	= ephemeris theory code; "0" is used for SGP4
SSSS	= origination code for TLES; this is set to "OATS' if generated by OATS

and where in the second line,

nnnnn	= satellite SDC number
III.IIII	= inclination (degrees)
NNN.NNNN	= right ascension of ascending node (degrees)
EEEEEEE	= eccentricity (decimal point implied such that 0.eeeeeee)
WWW.WWWW	= argument of perigee (degrees)
AAA.AAAA	= mean anomaly (degrees)
MM.MMMMMMMM	= mean motion (revolutions per day)
RRRRR	= 5 digit revolution number (leading zeroes are shown for 4 digits or less)

10.1.5 RUK12 INPUT FILES

The RUK12 orbit model accepts an osculating, Cartesian state vector as input. Although the components of the input state vector for this type of orbital element set are well-defined, the orbital element set file does not have a fixed native format for those components. The input file format for the RUK12 orbit propagation model that is used in OATS is as follows:

first data line :

x	= x position component in kilometers (real)
y	= y position component in kilometers (real)
z	= z position component in kilometers (real)

second data line

xdot	= x velocity component in kilometers (real)
ydot	= y velocity component in kilometers (real)
zdot	= z velocity component in kilometers (real)

third data line

year	= epoch year (real)
month	= epoch month (real)
day	= epoch day (real)

fourth data line

hours = epoch hours (real)

minutes = epoch minutes (real)

seconds = epoch seconds (real)

fifth data line

frame flag= integer flag specifying ECI (0) or ECF (1) coordinates

sixth data line

step = step size in seconds for the numerical integrator (real)

10.1.6 J2 INPUT FILES

The J2 orbit model accepts mean Keplerian orbital elements as input. Although the components of the input state vector for this type of orbital element set are well-defined, the orbital element set file does not have a fixed native format for those components. The input file format for the J2 orbit propagation model that is used in OATS is as follows:

first data line :

a = semi-major axis in kilometers (real)

e = eccentricity (real)

i = inclination in degrees (real)

second data line

Ω or α = argument of the ascending node in degrees (real); see fifth data line

ω = argument of perigee in degrees (real)

m or **t** = anomaly in degrees (real); see fifth data line

third data line

year = epoch year (real)

month = epoch month (real)

day = epoch day (real)

fourth data line

hours = epoch hours (real)

minutes = epoch minutes (real)

seconds = epoch seconds (real)

fifth data line

frame flag= integer flag specifying ECI (0) or ECF (1) coordinates; if ECI, α is right ascension of ascending node; if ECF, Ω is longitude of ascending node

anomaly flag = integer flag specifying mean anomaly **m** (0) or true anomaly **t** (1)

Charlie OLES

```
86622.6320071.8394858.00083.0002540.5181203.1292462.2360780940210
```

Z OLES

```
866221791163200716839485800008300025406518120371292462623607802920210
```

PME OLES

```
710398676193982778632018000040194434201979435850855661761975120330000
```

SGP4 TLES

```
1 88888U          80275.98708465  .00073094  13844-3  66816-4 0    8
2 88888  72.8435 115.9689 0086731  52.6988 110.5714 16.05824518   105
```

RUK12

```
   2000.19700000000     -6226.44500000000     2912.33600000000
   2.63547270000000      3.55260630000000     5.88467380000000
   1991.000000000000     11.0000000000000     10.0000000000000
   7.00000000000000      40.0000000000000     0.000000000000000
          0
   60.0000000000000
```

J2

```
   6700.00000000000     2.000000000000000D-02     35.0000000000000
   0.000000000000000    50.0000000000000          5.00000000000000
   1993.0000000000000   11.0000000000000          1.00000000000000
   0.000000000000000    0.000000000000000         0.000000000000000
          1              1
```

Figure 10-1. Sample Orbital Element Data Files

10.2 EPHEMERIS FILES

Ephemeris files generated by OATS contain header data followed by a consecutive listing of satellite state vectors (position+velocity) separated by a constant time increment. The files are ASCII character format with a sequential organization. If a user wishes to use an OATS ephemeris file in another application, it is necessary only to use an editor to strip off the header lines. The header is not a constant length--it will be two or three lines depending upon the orbit propagator used to generate the file. Header lines are easily recognized because they begin with the character field "OATS". The header allows the OATS software to access the ephemeris data more quickly; however, it is not a requirement for the ephemeris file to have a header for OATS to access an ephemeris. Ephemeris files generated by external software can be utilized if it has a constant time increment between state vectors, and if it follows the record format described as follows. The ECF coordinate system is described in Section 6.2. Each record contains the following space-delimited fields:

YYYY	= Year (integer)
MM	= Month (integer)
DD	= Day (integer)
hh	= Hour (integer)
mm	= Minutes (integer)
seconds	= Seconds (real)
x	= ECF x-position component in kilometers (real)
y	= ECF y-position component in kilometers (real)
z	= ECF z-position component in kilometers (real)
xdot	= ECF x-velocity component in kilometers/second (real)
ydot	= ECF y-velocity component in kilometers/second (real)
zdot	= ECF z-velocity component in kilometers/second (real)

10.3 TARGET FILES

The target input file allows the user to import a list of target positions into OATS for coverage analysis and provides a means to access multiple lists of targets for different types of analysis. A target file may be created by the user with any text editing program, or may be compiled using the OATS target interface and saved to a file using the *Save* option (see Section 7.5). The files are ASCII character format with a sequential organization. Each record must contain the data fields as shown below, with data fields delimited by at least one blank character. Target names may be any 32-character alphanumeric string--they may be as simple as a number identification or may even be left blank provided the length is preserved in

the file. Target names are not required to process targets within OATS, because a unique target is defined by a combination of all four data fields. The user is cautioned, however, that the interface used to display targets employs standard Macintosh scrollable windows that use the title to show the existence of a data entry in the list. Targets with blank names can be processed, highlighted, and manipulated in such lists, but it is extremely awkward to differentiate between members of a list with blank name fields. Coverage analysis printouts may also be confusing.

Name = target name, any 32-character alphanumeric string
Latitude = target geodetic latitude in degrees
Longitude = target longitude in degrees
Altitude= target height above the ellipsoid in kilometers

10.4 GROUND STATION FILES

The ground station input file allows the user to import a list of ground station positions into OATS for coverage analysis and provides a means to access multiple lists of ground stations for different types of analysis. A ground station file may be created by the user with any text editing program, or may be compiled using the OATS ground station interface and saved to a file using the *Save* option (see Section 7.6). The files are ASCII character format with a sequential organization. Each record must contain the data fields as shown below, with data fields delimited by at least one blank character. Ground station names may be any 32-character alphanumeric string--they may be as simple as a number identification or may even be left blank provided the length is preserved in the file. Ground station names are not required to process ground stations within OATS, because a unique ground station is defined by a combination of all five data fields. The user is cautioned, however, that the interface used to display ground stations employs standard Macintosh scrollable windows that use the title to show the existence of a data entry in the list. Ground stations with blank names can be processed, highlighted, and manipulated in such lists, but it is extremely awkward to differentiate between members of a list with blank name fields. Coverage analysis printouts may also be confusing.

Name = ground station name, any 32-character alphanumeric string
Latitude = ground station geodetic latitude in degrees
Longitude = ground station longitude in degrees
Altitude= ground station height above the ellipsoid in kilometers
Elevation Mask = ground station elevation mask in degrees above horizon

10.5 MAP FILES

OATS contains two internal map data bases which are adequate for the majority of map plotting functions for which OATS is expected to be utilized; however, OATS also provides the user the option of supplying his own map file for special mapping projects. A user's external map file should be in sequential ASCII format, and should be organized as a set of ordered data points that define geographic outlines in a "connect-the-dots" fashion. Record format is as defined below, with each data field being delimited by one blank character. Maps are plotted with the assumption that the basic global background is an ocean globe upon which other areas with defined outlines are added. These added areas may be presented as merely outlines, or plotted as solid areas (see Section 7.3) to simulate a photographic world map. In order to achieve a "world view" map, the added areas must be classified as land masses (continents or islands) and water masses contained wholly within land masses (lakes). The record format provides a flag for discriminating between the two area types. Such outline areas would most commonly be provided for continental boundaries, large bodies of water, and major islands; however, the format does not preclude use of a map file with geo-political outlines. The use of visible vs. invisible outlines allows solid areas to be plotted side-by-side without showing boundaries in an outline map (see Section 7.3). Latitude is expressed in radians from $-\pi$ to π and longitude is expressed in radians from 0 to 2π. A negative longitude value is used as a flag to signify the start of a new plot area.

Latitude = geodetic latitude in radians

Longitude = geodetic longitude in radians (negative value is a flag; see above)

Area Type Flag = a 1-character flag showing the area type

"G" = ground area, with visible outlines

"L" = lake area, with visible outlines

"g" = ground area, with invisible outlines

"l" = lake area, with invisible outlines

10.6 CONTOUR LEVEL FILES

These files are used to store levels for either the line contouring function or for the density contouring function. It is strongly recommended to use the OATS density interface to enter levels and colors and then do a *Save* to create a levels file (see Section 7.8); however, it is possible for experienced Macintosh users to create their own levels file externally. Files are very simple in format. They have a sequential ASCII format, and allow only one contour level per record. Levels are usually real number type data. They should be stored as character data, should not be negative, and should be sorted in ascending order by level value. Three integer numbers follow the contour level to record the colors used for density contours;

otherwise, all color values will be read from the file as zero valued which will result in all black density contours. Color level integers should lie between 0 and 65,535. Level and color numbers should be delimited in each record by at least one blank character.

10.7 CONTOUR FILES

The OATS graphical coverage functions (see Section 8.2) create a tabular file of data which is then used to plot coverage isochrones or a color-coded density map of satellite coverage. This contour file, is often written in compresed form to save storage space; however, it can also be saved in expanded character format for transport to other analytical programs or direct inspection by the user. If saved in expanded form, the file will be in sequential ASCII format and will consist of one line of header data followed by a number of data records dependent on the mesh size used by OATS to perform the graphical coverage run. The header record will have a character recognition string for OATS internal usage followed by two integers, **K** and **L**. These integers identify the number of latitude and longitude grid points in the coverage computation mesh. If **N** is the user selected grid spacing in degrees of latitude, then the number of grid elements on each meridian is **(L+1)** and:

```
L = 180 / N
```

Likewise, if **M** is the grid spacing in degrees of longitude, then the number of grid elements on each parallel is computed:

```
K = 360 / M
```

The remainder of the file beyond the header is made up of the **K*(L+1)** data records representing the grid points. The grid points can be mapped back to the latitude/longitude grid via the following algorithm:

For the **p**th record in the file (after the header record):

```
latitude  = i * 180 / L - 90          (in degrees)
longitude = (j- 1) * 360 / K          (in degrees)
```

where

```
i = INTEGER((p-1)/K)
j = p-(i*k).
```

and the **INTEGER** function converts a real number to an integer value with truncation.

Each individual coverage record will consist of five values representing the coverage level at its point in the mesh. In left-to-right order these data are:

- Cumulative coverage as a percentage of time
- Cumulative coverage as an average daily coverage (in minutes)
- Cumulative coverage as a total daily coverage value (in minutes)
- Average cover outage (minutes per day)
- Maximum cover outage (minutes per day)

OATS contouring functions can also be used to plot data created by an external program, and which is not necessarily related to satellite coverage. An artificial contour file can be created as an input to OATS for this process. In this case, the header record in the data file to be contoured should consist of only the integers **K** and **L** as defined above. This type of header will not have the OATS recognition character string, which identifies for OATS that the file is externally created. The remaining **K*(L+1)** records to be contoured in the file should contain only one data value in ASCII character format. It is suggested that records can be created by the external software using the following pseudo code:

```
Do for longitudes j = 1,2, ...,(L+1)
    Do for latitudes i = 1,2, ...,K
        write contour value for latitude j and longitude i
    End Do
End Do
```

10.8 ATTITUDE FILES

Attitude files are one of the newest additions to OATS. The program menu trees for **Plot** and **Coverage** (see Sections 7 and 8) frequently make it possible to define a spacecraft orientation through the use of attitude files. Although there is typically some association of ephemeris file to attitude file, it is not a requirement of the program that there be any pre-assignment. It is necessary that the time intervals overlap, but the interval between records need not be the same and the start and stop times do not need to be identical. All data is presumed to be stored in ASCII character format.

Attitude files have two header records, followed by n time-tagged attitude records. The first header record contains an integer mission number. The format is non-critical, and can be followed by a delimiting blank space and any user-defined data of interest. The second header record contains an integer flag (format again non-critical) identifying the type of data contained in the file. Appendix A elaborates further on this

issue. The file types indicated by the flag are: 1 = pitch/roll/yaw data, 2 = right ascension/declination, and 3 = perifocal X/Y/Z. Each subsequent record contains the following space-delimited data fields:

time record = $_{b}$DD-MMM-YYYY$_{b}$HH:MM:SS.SS

angle1 = floating point

angle2 = floating point

angle3 = floating point

The very exact format of the time record is intentional and historical in nature--it matches the format of attitude files supplied to the authors of the software and used in their analyses. The various sub-fields in the time record imply, day, month (e.g. SEP for September), year, hours, minutes, and decimal seconds. The "$_{b}$" stands for a blank space. The specific definition of the angle data depends on the file type. If file type 1, angle data is pitch, roll, and yaw in degrees. If file type 2, angle data is right ascension and declination in degrees with angle 3 undefined and unnecessary. If file type 3, angle data is unitless vector components in the perifocal coordinate system. The convention for ordering the unit vector components is perigee direction, orbit normal direction, then orbit normal cross perigee dorection.

SECTION 11 - OATS FAST-START: SAMPLE PROBLEMS

OATS is an analytical environment. It is also very much a Macintosh-style program in that there is no straight-through "in one end and out the other" linear processing of data. The order and fashion in which the menus and processes are exercised are limited primarily by the user's requirements and imagination. Because of the wide-ranging scope of OATS and because of its non-linear nature, it is not possible to present a comprehensive set of examples of all procedures and outputs of which OATS is capable. This section, however, will attempt to show a few practical, typical examples of the use of OATS and the results that should be expected. The examples are presented as a sample introductory session that is written for the beginning user to follow along and to use to duplicate known results. In the course of this training exercise the user can gain some familiarity with basic functions. Not all important capabilities are presented.

Through the discussion of these introductory examples, most menu selections will involve sub-menu choices. As a shorthand representation, these menu selections will be shown:

Menu/Sub_Menu_Level1/Sub_Menu_Level2

11.1 SETTING THE ENVIRONMENT

After opening the OATS program from the Macintosh window, the OATS Graphics Window should appear as the only open program window. It is now referred to as the active window. Although the environment settings used in the distribution version of OATS should be functional as initial values for all users, most users will want to maximize the Graphics Window. Using the menu selection of **Window/Graphics Options/Graph Setup** will bring up the dialog shown in Figure 5-12. Since it is recommended that OATS be used with a square window, the user should choose the equal values of *width* and*height* that you think will still fit on the screen. Characteristically good values are a few hundred pixels--a few thousand pixels is probably pushing the limit. Verify that *Pages* settings are 1 by 1. Push the *Apply* button to make the new window sizes active. If you are confident that you want to keep the new values, push *Save*. Otherwise, the new values will be active only during this execution of OATS. Exit the dialog with *OK*. A drag box appears in the lower right hand corner of the Graphics Window. The user should use the cursor to click-and-grab the window corner and stretch it to its maximum height and width. If you guessed too large on the window size, the scroll bars at the bottom and left of the window will be active. Although there is nothing wrong with such a set-up, it is recommended that the initial user should repeat the window sizing process until a size is achieved that is square, fills most of the screen, and leaves the scroll bars inactive. The screen should appear as shown in Figure 4-4.

11.2 CREATING AN EPHEMERIS FILE

Since OATS is an ephemeris-driven program, the first order of business is usually to construct an ephemeris file. Making the menu selection of **Propagate/Select Model/J2** will bring up the dialog shown in Figure 6-6. All data fields should be set to zero, except for the epoch. Note that 1970 is the zero-point in the time scale used by OATS routines. Pushing the *File* button will bring up the standard Macintosh file interface, which can be used to locate and select (highlight) the file called J2_ORBITAL_ELEMENTS which has been provided with the OATS program as a sample orbital elements file. Selecting *OPEN* from this standard dialog will return the user to the J2 propagator dialog, which should appear with all orbital elements set as shown in Figure 11-1.

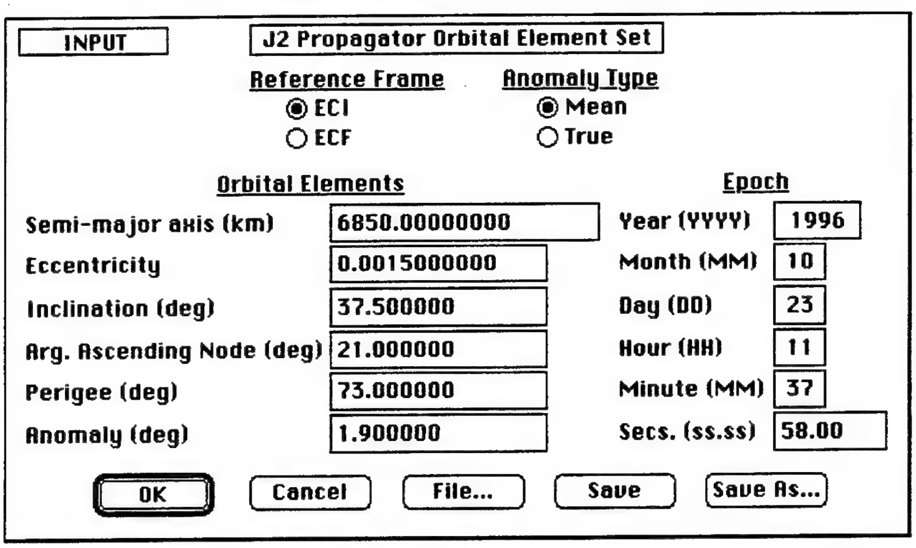


Figure 11-1. Example Orbital Elements Dialog with Elements in Place

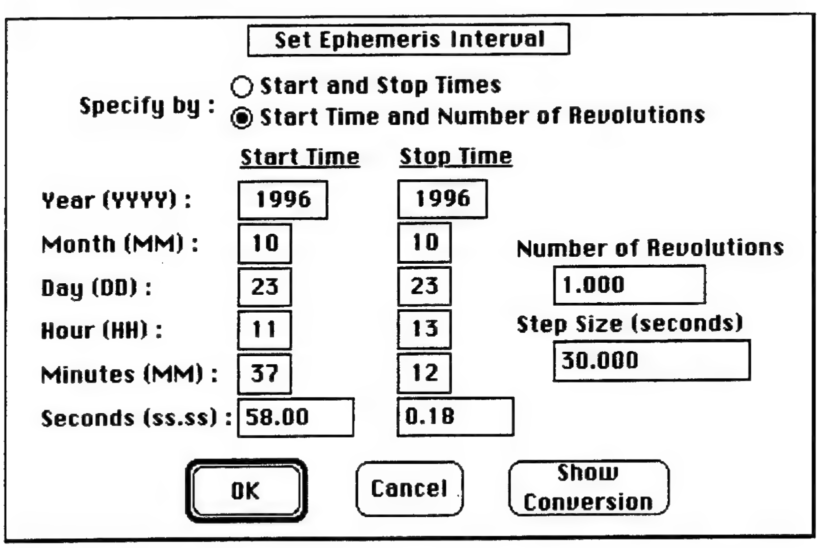


Figure 11-2. Example Ephemeris Interval Dialog with Selections in Place

Pushing the *OK* button will bring up the dialog shown in Figure 6-13, which is used to set the ephemeris interval. The *Start Time* will already be set to the *Epoch* used in the orbital elements. Selecting the radio button *Start Time & Number of Revolutions* will make the *Number of Revolutions* active. This parameter should be set to 1.0 for this example. *Step Size* should be set to 30.0 seconds, and the user should also push *Show Conversion* to verify the *Stop Time*. The result should show an interval running from 10-23-1996 at $11^h37^m58.00^s$ to 10-23-1996 at $13^h12^m0.18^s$. Figure 11-2 shows the expected appearance of the interval dialog after the conversion button has been clicked. Selecting *OK* will return the user to the main menu. At this point, all preparations to generate an ephemeris have been completed.

Select **Propagator/Run Propagator** to initiate ephemeris generation. The Macintosh standard file interface will appear to allow the user to select a location and name for the *New Ephemeris File*. For this example call the file J2_USER_EPHEMERIS and select the same directory as the OATS executable. Select *SAVE* to begin the file generation. A progress display graphic will be presented showing the file name, a tabular value of percentage of file completed, and a fill-bar graphic showing progress toward completion. When file generation is completed, the graphic will disappear, you will briefly see a note implying that file is being placed in the active files list, and then the program will return to the main menu. The ephemeris file which is generated will appear as in Figure 11-3. Note that the middle portion of the file has been deleted for brevity.

```
OATS KEP19961023113758.00199610231312 0.00J2_USER_EPHEMERIS        23-OCT-9611:08:42   30.00     189
OATS  0 0 1996 10 23 11 3758.00  0.68500000000000E+04   0.00150000000000
OATS   37.50000000000000 21.00000000000000 73.00000000000000  1.90000000000000
1996 10 23 11 37 58.00  -2288.950611  -5087.990536  4020.108461    6.817055   -2.131185    1.211314
1996 10 23 11 38 28.00  -2083.061770  -5099.609430  4054.255524    6.889517   -1.972423    1.060103
1996 10 23 11 38 58.00  -1875.101598  -5156.433082  4083.838209    6.954967   -1.811759    0.907689
1996 10 23 11 39 28.00  -1665.281759  -5208.406621  4108.823269    7.013339   -1.649342    0.754276
1996 10 23 11 39 58.00  -1453.815769  -5255.479693  4129.182657    7.064575   -1.485324    0.600006
1996 10 23 11 40 28.00  -1240.918776  -5297.606519  4144.893557    7.108625   -1.319859    0.445066
          . . .             . . .            . . .           . . .          . . .
          . . .             . . .            . . .           . . .          . . .
1996 10 23 13  9 58.00  -4699.154984  -3135.288305  3856.220857    4.841171   -5.096618    1.753604
1996 10 23 13 10 28.00  -4551.444601  -3286.900602  3906.760553    4.991369   -4.998582    1.608225
1996 10 23 13 10 58.00  -4399.300606  -3435.495846  3952.901923    5.136421   -4.895599    1.461084
1996 10 23 13 11 28.00  -4242.879692  -3580.926832  3994.592986    5.276186   -4.787761    1.312198
1996 10 23 13 11 58.00  -4082.342777  -3723.049214  4031.786795    5.410527   -4.675167    1.161884
```

Figure 11-3. Example Generated Ephemeris File

11.3 PLOTTING AN EARTH MAP

Before plotting a map to use as a background for a plot of satellite orbit characteristics, parameters defining the map should be set in three interface dialogs. The first defines the map projection and is shown in Figure 7-42. The map projection is the mathematical model that translates a three-dimensional globe onto a two-dimensional screen and defines the overall appearance of the map. The projections dialog is entered with the menu selection of **Plot/Map/Projections**. For this example, set the radio button for a *Rectangular* plot and the limits such that:

```
Min. Lat.   =   -90          Max. Lat.   =   90
Min. Long.  =  -180          Max. Long.  =  180
```

Exit from this dialog with an *OK*, and choose **Plot/Map/General Options** to open the dialog shown in Figure 7-44. The options displayed in this dialog allow the user to select a variety of large-scope options defining the map appearance. For this example, the options are set as shown in Figure 11-4. The last dialog that should be visited is shown in Figure 7-45, and comes from choice of the **Plot/Map/Label** Options command. It is sufficient to note for now that the options to draw and label the latitude/longitude coordinate grid should be turned on. Upon exiting the this last dialog with an *OK*, the user is returned to the main menu. The map is plotted by selecting the menu command **Plot/Map/Plot Map**. The resulting map is shown in Figure 11-5. Note that this drawing is composed of 5 layers, and that if desired you can see the stacking of layers by opening the Graphics Tools Window.

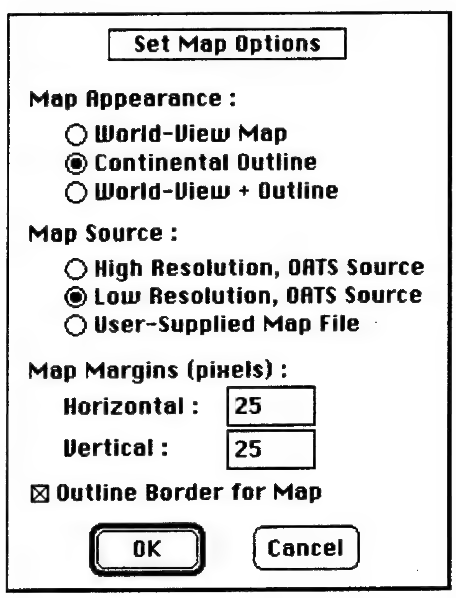


Figure 11-4. Example Map Plot General Options Dialog

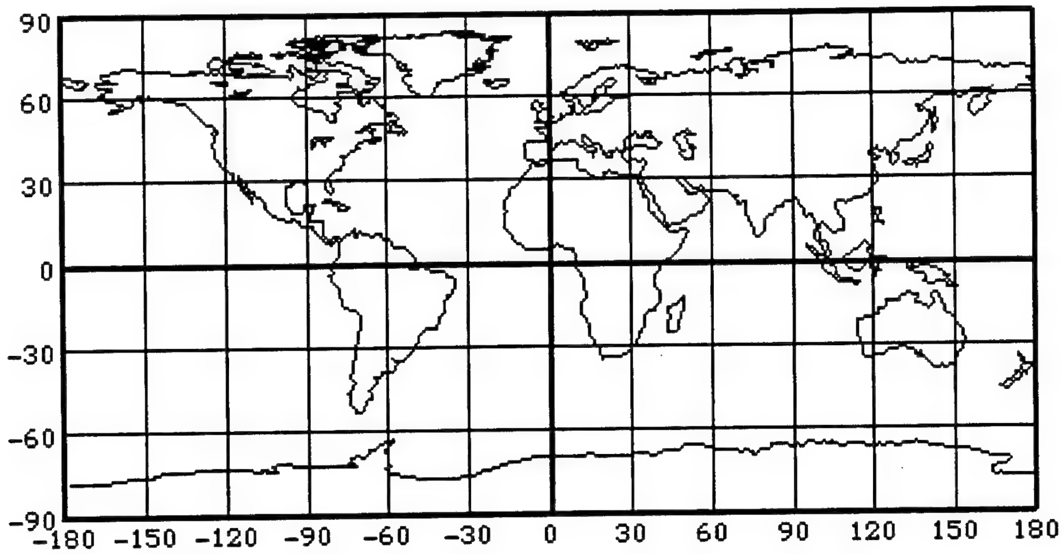


Figure 11-5. Example Map Plot

11.4 <u>PLOTTING GROUND STATIONS</u>

Since satellite coverage is often linked to the existence of a ground station, the next step in this quick start exercise is to plot ground stations on the map. OATS is supplied with a short list of sample ground stations in the file SAMPLE_GS_FILE. These can be accessed with the menu selection of **Plot/Ground Station Position/Options**, which brings up the interactive interface shown in Figure 7-19. There is a great deal of depth to this dialog, and the user is referred to Section 7.6 for details. For this introductory exercise, two ground stations will be plotted. *Open File* brings up the standard Macintosh file interface. Locate the SAMPLE_GS_FILE, highlight it, and press *Open*. This returns you to the OATS dialog, with the list of ground stations in the *Cataloged G.S. List.* Use the *Sort* button to sort the acquired list. Highlight "Maui", click on *Select*, and note that Maui is copied to the *Active G.S. List*. Repeat this process for the Aerecebo station. The dialog should appear as shown in Figure 11-6. Select *OK* to exit from the dialog to the main menu. Visit the **Plot/Ground Station Position/Icon Options** dialog (Figure 7-22) in order to verify that the *Icon Plot Size* is 12 and the *Plot GS Names* and *Erase Name Background* flags are turned on. At this point, use the menu selection of **Plot/Ground Station Position/Plot** to produce a plot of the Maui and Aerecebo ground stations on the original map. The result will appear as in Figure 11-8.

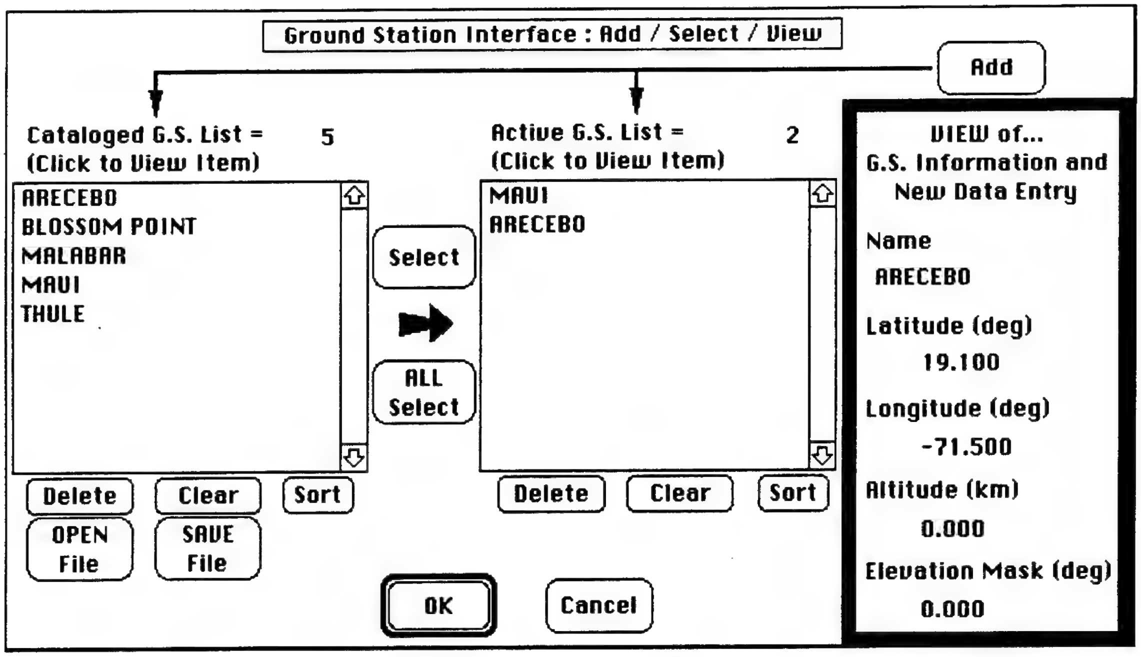


Figure 11-6. Example Ground Station Position Dialog with Two Active Stations

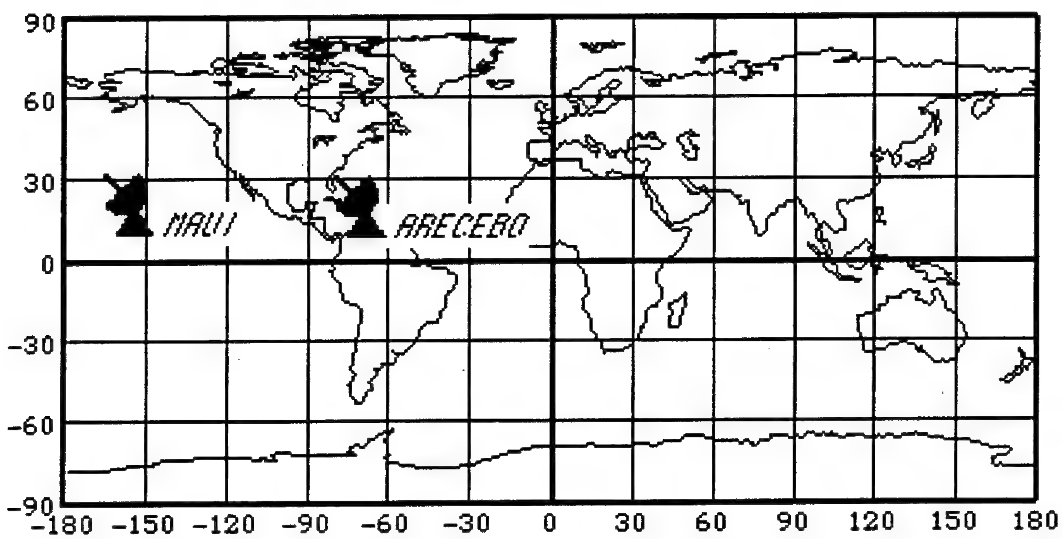


Figure 11-7. Example Map Plot with Ground Stations

11.5 PLOTTING SATELLITE TRACK

OATS provides options for plotting satellite position, FOV, track, and swath. These procedures are generally similar, so only a satellite track will be plotted in this example. Selecting the **Plot/Satellite Tracks/Options** from the OATS menu system will bring up the dialog for tracks shown in Figure 7-6. Only one file will appear in the *Ephemeris File List*, the J2_USER_EPHEMERIS file which was created in

Section 11.2. The track interval will be taken from this file, with a *Start Time* of 10-23-1996 at $11^h37^m58.00^s$ and a *Stop Time* of 10-23-1996 at $13^h12^m0.00^s$. Since the *Map Type* projection is Rectangular, all controls for the *Space Track* will be inactive. Exiting this dialog with an *OK* will return the user to the main menu. Verify that the **Plot/Satellite Tracks/Line Definition** dialog indicates solid lines. The **Plot/Satellite Tracks/Time Tags** selection provides a number of options for placing time tags on a satellite track. An appropriate set of options for this introductory problem is shown in Figure 11-8. At this point, use the menu selection of **Plot/Satellite Tracks/Plot** to add a plot of the satellite ground track to the map. The result will appear as in Figure 11-9.

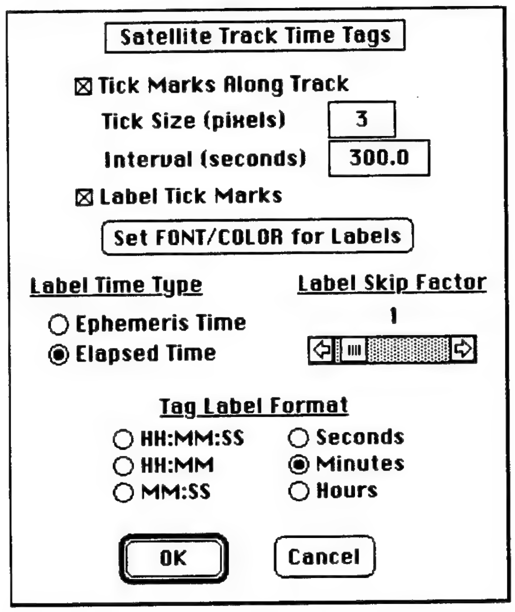


Figure 11-8. Time Tag Selections for Satellite Track

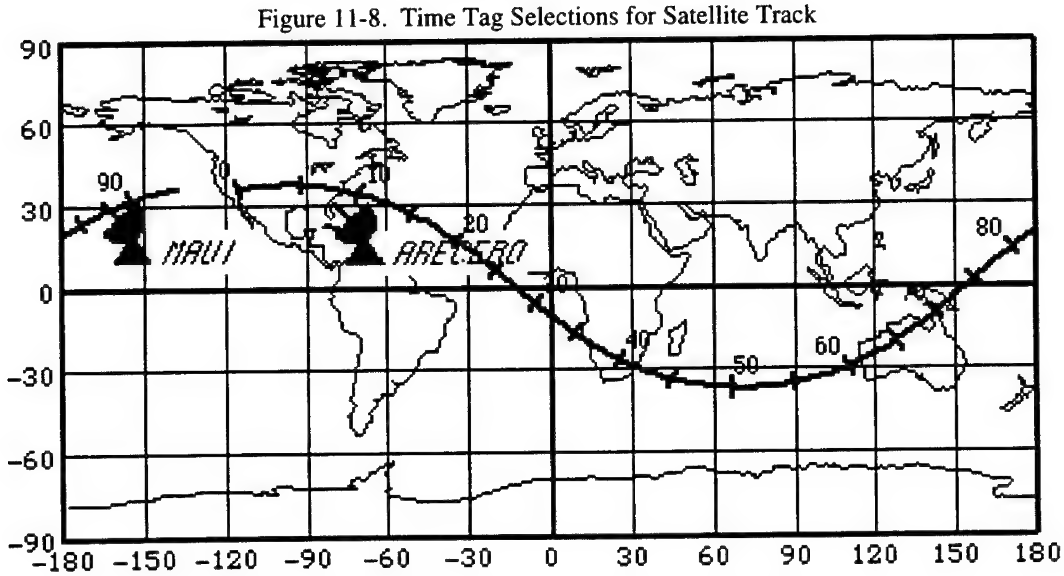


Figure 11-9. Example Map Plot with Satellite Track

11.6 COMPUTING TABULAR COVERAGE

The tabular coverage function computes satellite coverage for a system of satellites with known antenna and attitude parameters against a set of ground targets, with ground station visibility used as an optional coverage constraint. In this example, the single ephemeris file and the two ground stations already selected will be used. Tabular coverage results are saved as an output file and are presented to the user in the Normal Text Window. In order to view the data as it is generated, check that *Tabular Coverage Computations* is selected in the menu selection **/System Params**.

Before executing the command to compute tabular coverage results, it is necessary to visit three dialogs and set required parameters. The menu selection of **Coverage/Tabular/Edit Ground Stations** will bring up the same dialog viewed when plotting ground stations (see Section 11.4). Since the Maui and Aerecebo stations have already been selected as part of a previous exercise, no further action is required here. Use the **Coverage/Tabular/Edit Targets** menu selection to bring up the dialog shown in Figure 7-16. The form and function is very similar to that for the ground station dialog. OATS is supplied with a short list of three sample targets in the file SAMPLE_TARGET_FILE. *Open File* brings up the standard Macintosh file interface. Locate the file, highlight it, and press *Open*. This returns you to the OATS dialog, with the list of targets in the *Cataloged Target List.* Click on *Select All* and note that all three targets are copied to the *Active Target List.* Select *OK* to exit from the dialog to the main menu. The **Coverage/Tabular/Set Constraints** menu selection will bring up the dialog shown in Figure 8-3. This dialog allows the user to assign four sets of viewing constraints to each ephemeris file in the active list, including antenna, attitude, ground station, and target constraints. In this example there is only one satellite and, therefore, only one ephemeris file and one set of constraints. For this example, push *GROUND STATION Constraints* to show the dialog described in Figure 8-4. Set the constraint *ON*, move *ALL* stations into the validated list, and select for *ANY* visible station. These settings specify that the satellite must be simultaneously in view of a target and any ground station in order to satisfy the conditions for coverage. For ANTENNA Parameters, select a *Cone half-angle* antenna pattern using a *Primary Angle* of 75 degrees.

Now that the initial parameters are set, use the menu selection of **Coverage/Run Tabular** to initiate a tabular coverage run. The dialog shown in Figure 8-6 will appear. The *Start Time* and *Stop Time* for the J2_USER_EPHEMERIS will already be entered into the dialog. Set the *Step Size* at 30 seconds and mark both checkboxes to *Print Up/Down Times* and to implement *Atmospheric Refraction Correction*. Select *OK* to start the tabular coverage computation run. The Macintosh standard interface will appear, asking for a name for the *Tabular Output File* of coverage data. Enter USER_TABULAR_FILE and click on the

Save button. The results seen in Figure 11-10 will appear in the Tabular Window and in the user-designated file.

All parameters involved in the tabular coverage run will be repeated in the header data. In this example, TARGET1 shows zero coverage because it lies outside the area viewed by the satellite. TARGET3 also shows zero coverage even though it is within the area seen by the satellite, because no ground station is within view. TARGET2 is covered by the example satellite, and shows single rise (UP) and set (DOWN) times for the pass in the J2_USER_EPHEMERIS file. All coverage values are represented by abbreviations, where:

For coverage time, the interval between AOS and LOS:

NCOV	-	Number of intervals covered (in view)
COVMIN	-	Coverage time minimum in any pass (in minutes)
COVMAX	-	Coverage time maximum in any pass (in minutes)
COVAVG	-	Coverage time average of all passes (in minutes)
COVSTD	-	Coverage time standard deviation for all passes (in minutes)
COVTOT	-	Coverage time total of all passes (in minutes)
AVGCOV	-	Average daily coverage time for ephemeris interval (minutes per day)
PCTCOV	-	Percent of time covered

For outage time, the interval between LOS and AOS:

NOUT	-	Number of intervals not covered (out of view)
OUTMIN	-	Outage time minimum (in minutes)
OUTMAX	-	Outage time maximum (in minutes)
OUTAVG	-	Outage time average (in minutes)
OUTSTD	-	Standard deviation in outage time (in minutes)
OUTTOT	-	Outage time total (in minutes)
AVGOUT	-	Average daily outage time for ephemeris interval (minutes per day)

For revisit time, the interval between one AOS to the next AOS:

NREV	-	Number of times revisited
REVMIN	-	Revisit time minimum (in minutes)
REVMAX	-	Revisit time maximum (in minutes)
REVAVG	-	Revisit time average (in minutes)
REVSTD	-	Standard deviation in revisit time (in minutes)
REVTOT	-	Revisit time total (in minutes)

```
DEFINE SATELLITE COVERAGE COMPUTATION

Start Time (Y,M,D,h,m,sec):  1996 10 23  11 37 58.000000

Stop Time  (Y,M,D,h,m,sec):  1996 10 23  13 12  0.000000

Time Increment:      30.000000 seconds

Computational Options --   Print Up/Down Times: YES    Atmospheric Refraction: YES

Tolerance for up/down time bisection algorithm:       0.010000 seconds


ACTIVE GROUND STATION(s) :    2 STATIONS

 1 ARECIBO                          LAT,LON(deg)  19.100 -71.500  ALTIT(km)   0.000  MIN.ELEV(deg)    0.000

 2 MAUI                             LAT,LON(deg)  20.700 203.700  ALTIT(km)   3.030  MIN.ELEV(deg)    0.000


SATELLITE EPHEMERIS FILES :    1 FILES

 1 J2_USER_EPHEMERIS

     GS Constraint: YES      determined by ANY of ground stations:  1  2

     Annulus FOV:   NO

     Sat. Sensor Pattern:   CONE ANGLE            75.00000 deg

     Attitude Constraint:   NO


TARGET COVERAGE Based on Visibility of AT LEAST  1 Satellites


TARGET SUMMARY:   3 TARGETS

     LAT(deg)   LONG(deg)   ALT(km)   Name

 1      35.00        0.00      0.00   TARGET1

 2      20.80      271.10      0.00   TARGET2

 3     -14.80      142.30      0.50   TARGET3
__________________________________________________________________________

TARGET NO.   1   NAME: TARGET1                          LAT:   35.00  LON:     0.00  ALT:    0.00 KM


PASS STATISTICS (MINUTES)

UP                    DOWN                   COVERAGE  OUTAGE  REVISIT


COVERAGE STATISTICS (MINUTES):

 NCOV:        0  NOUT:        0  NREV:        0

COVMIN:  ********  OUTMIN:  ********  REVMIN:  ********
```

Figure 11-10. Example Tabular Coverage Output (1 of 2)

```
COVMAX: ******** OUTMAX: ******** REVMAX: ********

COVAVG:     0.00 OUTAVG:     0.00 REVAVG:     0.00

COVSTD:     0.00 OUTSTD:     0.00 REVSTD:     0.00

COVTOT:     0.00 OUTTOT:     0.00 PCTCOV:     0.00

AVGCOV:     0.00 AVGOUT:     0.00 MINUTES/DAY
```

```
TARGET NO.   2  NAME: TARGET2                    LAT:  20.80  LON: 271.10  ALT:   0.00 KM


PASS STATISTICS (MINUTES)

UP                    DOWN                    COVERAGE  OUTAGE  REVISIT

1996 10 23 11 44 15.0  1996 10 23 11 48  7.0     3.9     6.3     0.0


COVERAGE STATISTICS (MINUTES):

  NCOV:        1  NOUT:        1  NREV:        0

COVMIN:     3.87 OUTMIN:     6.28 REVMIN: ********

COVMAX:     3.87 OUTMAX:     6.28 REVMAX: ********

COVAVG:     3.87 OUTAVG:     6.28 REVAVG:     0.00

COVSTD:     0.00 OUTSTD:     0.00 REVSTD:     0.00

COVTOT:     3.87 OUTTOT:     6.28 PCTCOV:     4.11

AVGCOV:    59.22 AVGOUT:    96.21 MINUTES/DAY
```

```
TARGET NO.   3  NAME: TARGET3                    LAT: -14.80  LON: 142.30  ALT:   0.50 KM


PASS STATISTICS (MINUTES)

UP                    DOWN                    COVERAGE  OUTAGE  REVISIT


COVERAGE STATISTICS (MINUTES):

  NCOV:        0  NOUT:        0  NREV:        0

COVMIN: ******** OUTMIN: ******** REVMIN: ********

COVMAX: ******** OUTMAX: ******** REVMAX: ********

COVAVG:     0.00 OUTAVG:     0.00 REVAVG:     0.00

COVSTD:     0.00 OUTSTD:     0.00 REVSTD:     0.00

COVTOT:     0.00 OUTTOT:     0.00 PCTCOV:     0.00

AVGCOV:     0.00 AVGOUT:     0.00 MINUTES/DAY
```

Figure 11-10. Example Tabular Coverage Output (2 of 2)

11.7 CREATING A GRAPHICAL COVERAGE FILE

The graphical coverage function computes world wide coverage on a global grid for a system of satellites and ground stations. Satellites may operate out of view of the ground stations or they may be constrained to operate only while in view of a ground station. Graphical coverage analysis is done using a computed coverage file as an intermediary. In order to create this file, it is necessary to visit three setup dialogs and set required parameters. The menu selection of **Coverage/Graphical/Edit Ground Stations** will bring up the same dialog viewed when plotting ground stations (see Section 11.4) and when computing tabular coverage. Likewise, the menu selection of **Coverage/Graphical/Set Constraints** will bring up the same dialog viewed when selecting the antenna and ground station constraints under the computing tabular coverage function. The principal difference is that target constraints are not implemented in graphical coverage analysis and their control button is deactivated. Since the remaining parameters were already set in the last example, no further action is required. The third setup dialog is shown in Figure 8-8, and is accessed with the **Coverage/Graphical/Edit Mesh** menu selection. The default mesh size of 5 degrees square will be adequate for this example, so *OK* can be clicked to exit the dialog. The final suggested preparatory step is to visit the **/System Params** and verify that the *Show Summary Data* is checked.

Summary of Product Data File

	Percentage of Time	Average Daily Coverage	Total Cumulative Coverage	Average Outage	Maximum Outage
Maximum	11.70	168.45	11.00	94.50	94.50
Minimum	0.00	0.00	0.00	83.50	6.50
Mean	0.61	8.81	0.58	93.92	89.16

Longitude Mesh Size (deg) 5 Latitude Mesh Size (deg) 5

OK Save Data

Figure 11-11. Example Graphical Coverage Summary Data

The **Coverage/Run Graphical** menu selection will initiate computation of the graphical coverage file by bringing up the dialog shown in Figure 8-9. *Start Time* and *Stop Time* should already be set from the J2_USER_EPHEMERIS and *Step Size* was set in a previous dialog. After verifying that the *Data Compression* flag has been checked to keep the coverage file to a minimal size, the *OK* button should be clicked. The Macintosh standard file interface will appear, allowing the user to select a location and name for the *New Coverage Data File*. For this example, call the file USER_COVERAGE_FILE and select *Save*

to begin the file generation. A progress display graphic will be presented twice, because the compilation of the coverage file is a two-step process. This graphic shows the file name, a tabular value of percentage of file completed, and a fill-bar graphic showing progress toward completion. When file generation is completed, a graphic like that seen in Figure 11-11 will appear. After examining it, click *OK* to return to the main menu.

11.8 PLOTTING LINE COVERAGE CONTOURS

Line contours showing isochrones of satellite coverage can be plotted using the coverage file created in Section 11.7. The Graphics Window should again be the active window because it is used for output of the contours. If not, the menu selection **Window/OATS Graphics Window** will bring it to the front. Next select **Plot/Line Contours/Options** to bring up the line contouring options dialog shown in Figure 7-30. *Contour Levels* can be loaded quickly using the *OPEN File* button, which brings up the standard Macintosh file interface. Identify and highlight the file SAMPLE_LEVELS_LIST which is provided with the OATS program, and enter *OPEN* to return to the line contours dialog. Verify that the *Cumulative Coverage* and *Percentage of Time* radio buttons have been selected. The meaning of these coverage choices is explained in Section 7.9. Verify that the *Labeling of Contour Values* is turned *ON* and that the *INTEGER Values* button has been selected under **Plot/Line Contours/Line Labels**. The line contours dialog has a great more depth than may be indicated from this basic example--the user is referred to Section 7.9 for more details. Selecting *OK* returns the user to the main menu.

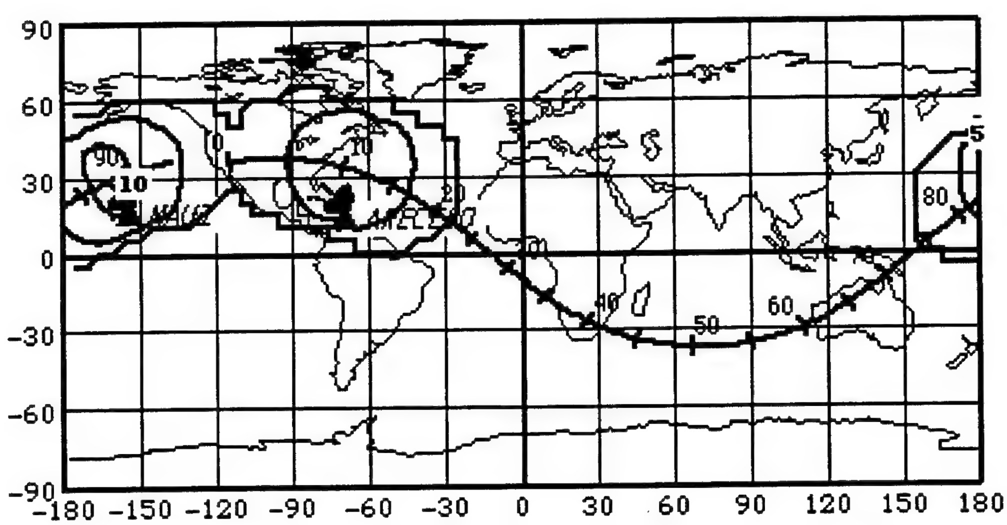


Figure 11-12. Example Map Plot with Line Coverage Isochrone Contours

Plotting of the line contours is initiated by the menu selection **Plot/Line Contours/Plot**. The Macintosh standard file interface dialog will appear, from which the user should select the USER_COVERAGE_FILE. Clicking the *OK* will produce the line coverage diagram shown in Figure 11-12.

11.9 LOOK-ANGLE ANALYSIS

Look-angle coverage analysis is used to produce a tabular list of data describing where and when a ground station will be able to view a satellite as it passes overhead. This coverage analysis also requires that initial parameters be set in three setup dialogs, but none of these is shared with the previous functions.

The menu selection of **Coverage/GS Look Angles/Select GS** brings up the dialog shown in Figure 8-12. For this example, click on the Aerecebo station to make it active and exit with an *OK*. The **Coverage/GS Look Angles/Select Ephemeris File** menu is used to select a file for analysis from the list of open ephemeris files as seen in Figure 8-13. This dialog must be visited to identify the file for the program, even if only one file is open. The third setup dialog is shown in Figure 8-14 and is brought up by choosing **Coverage/GS Look Angles/Set Frequencies**. It is used to set the uplink and downlink communication frequencies so that signal attenuation may be computed. In this example, the *Link Margin* flag should be turned off and the dialog exited with an *OK*.

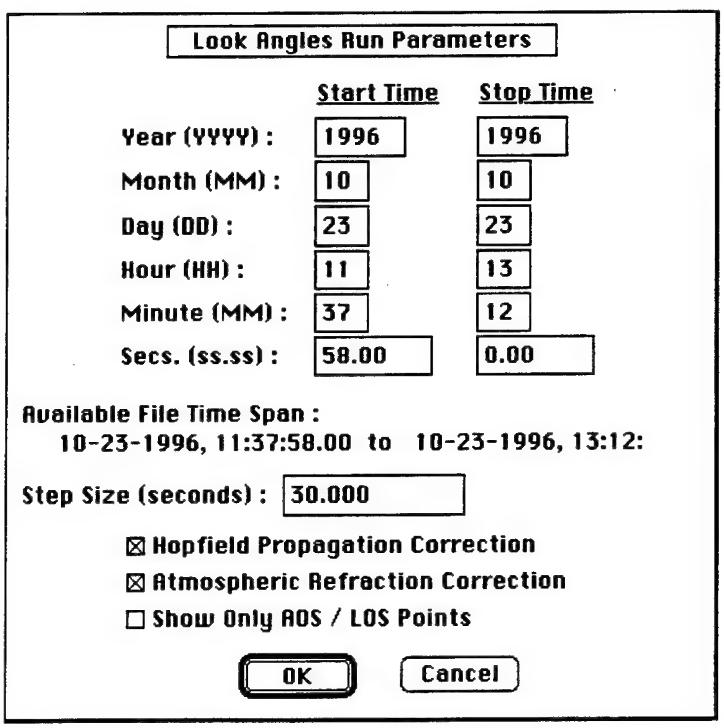


Figure 11-13. Example Look Angles Dialog with Parameters Set

The look-angles computations are initiated by selecting **Coverage/Run GS Look Angles**. The dialog shown in Figure 8-12 will be displayed. The *Start Time, Stop Time*, and *Step Size* will already be set from previous examples. The user should verify that Hopfield Propagation and Atmospheric Refraction checkboxes are marked as shown in Figure 11-13, and exit the dialog with an *OK*. The Macintosh standard file interface will appear and should be used to assign a *Look Angles File* name for the look-angle computations. Computations will be shown in the Tabular Window and will also be echoed in the output file. Exiting the standard interface with a *Save* produces the output shown in Figure 11-14. Note that the middle sections of the output have been removed for brevity. All data relevant to the look-angle setup is displayed in the output header data.

COMPUTE PASS STATISTICS

Start Time (Y,M,D,h,m,sec): 1996 10 23 11 37 58.000000

Stop Time (Y,M,D,h,m,sec): 1996 10 23 13 12 0.000000

Time Increment: 30.000000 seconds

Computational Options — Hopfield Correction: YES Atmospheric Refraction: YES Link Margins: NO AOSLOS Only: NO

Ground Station Name : ARECIBO

LAT,LONG(deg) 19.100 -71.500 ALTIT(km) 0.000 MIN.ELEV(deg) 0.000

Complete Date YR	MO	DY	Hr	Mi	Secs	Azimuth (Deg)	Elevation (Deg)	Range (Km)	RangeRate (Km/Sec)	RangeRate (PPM)	Shadow Status	AOS/ LOS
1996	10	23	11	44	14.97	327.9379	-0.0008	2556.2237	-4870.0198	-16.2445	- -	!AOS
1996	10	23	11	44	28.00	329.4394	0.5576	2493.3810	-4760.5999	-15.8795	- -	
1996	10	23	11	44	58.00	333.1878	1.6463	2354.5589	-4471.5929	-14.9155	- -	
1996	10	23	11	45	28.00	337.3828	2.7926	2225.2760	-4123.7180	-13.7551	- -	
1996	10	23	11	45	58.00	342.0700	3.9570	2107.4340	-3708.1470	-12.3690	- -	
1996	10	23	11	46	28.00	347.2834	5.0853	2008.1858	-3217.2587	-10.7316	- -	
					...	...	...	...	...	...		
1996	10	23	11	50	58.00	46.3001	5.4502	1973.6957	3053.4030	10.1851	- -	
1996	10	23	11	51	28.00	51.6800	4.3488	2073.3159	3570.4954	11.9100	- -	
1996	10	23	11	51	58.00	56.5256	3.1909	2187.2984	4010.4861	13.3776	- -	
1996	10	23	11	52	28.00	60.8643	2.0835	2313.4228	4380.1860	14.6108	- -	
1996	10	23	11	52	58.00	64.7393	0.9245	2449.7049	4688.1961	15.6383	- -	
1996	10	23	11	53	21.30	67.4601	0.0008	2561.4434	4890.5138	16.3131	- -	!LOS

Figure 11-14. Look-Angle Example Computations

11.10 SNAPSHOT EXAMPLE

As the final exercise in these quick-start examples, a snapshot will be generated. It is necessary to have at least two satellites to define a meaningful snapshot. The first can be the J2_USER_EPHEMERIS generated in Section 11.2. The second will be called J2_USER_EPHEMERIS2 and can be generated by the user in the same fashion as the first, except that an inclination of 55 degrees can be used to make the ephemeris a little different. For this very simple example, no ground stations or constraints are used. With the **Plot/Coverage Snapshot/Select** menu option, the dialog shown in Figure 7-36 will appear. Selection of *New* permits the user to define a new snapshot, the parameters for which are shown in Figure 11-15. Note that both of the active ephemeris files are chosen for the snapshot, a title is required, a time of 11^h40^m is chosen, and the snapshot is defined as the intersection of the FOVs.

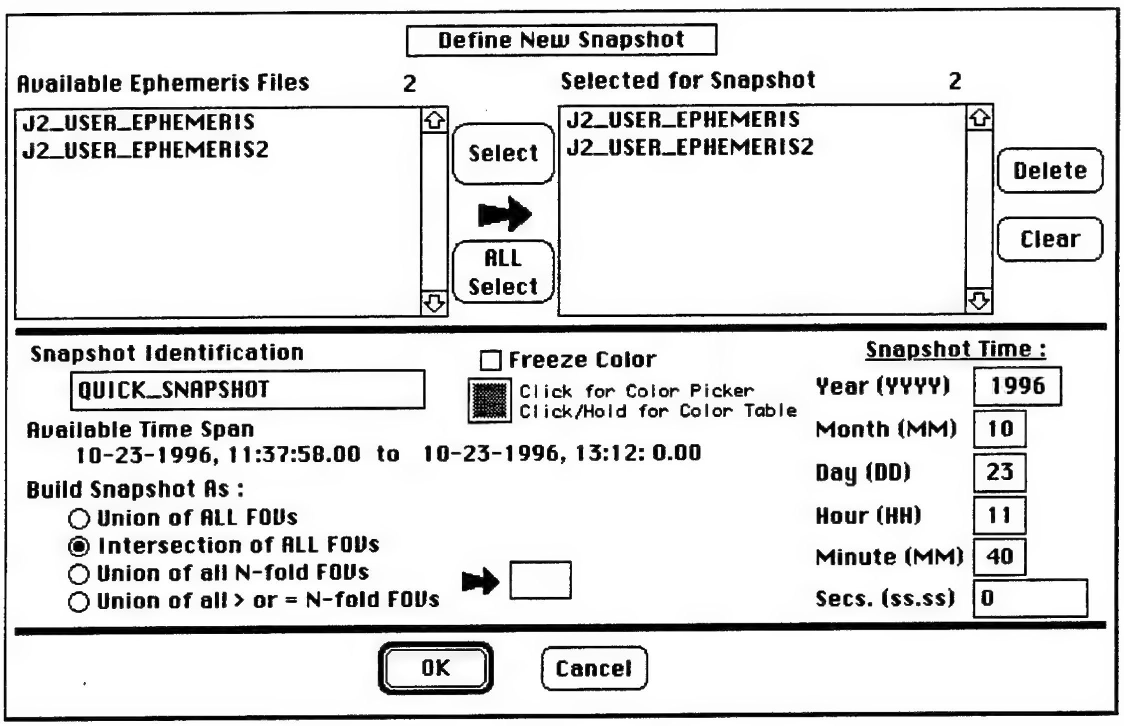


Figure 11-15. Definition of Quick-Start Snapshot

Implementing the **Plot/Coverage Snapshot/Plot** or the **⌘-H** command-key yields a snapshot plot like that seen in the shaded area in Figure 11-16. In order to clarify the snapshot, the background map, the two satellite tracks, and the outlines of the two FOVs at the designated time are also plotted. The **Plot/Coverage Snapshot/Statistics/Compute** command will reveal that this snapshot covers an area of 9351363.904 km^2 when a grid size of 6.0 degrees is utilized.

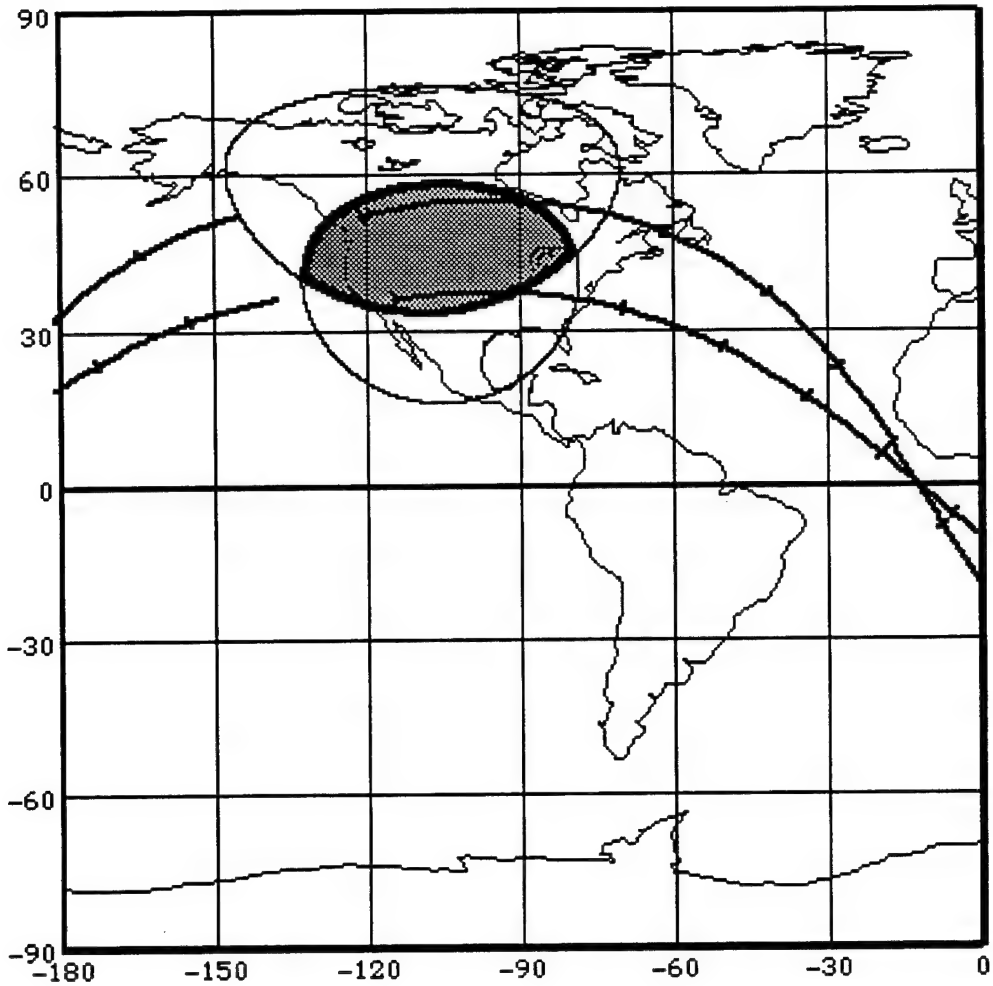


Figure 11-16. Plot of Sample Snapshot

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9. <u>Map Projections--A Working Manual</u> (U.S. Geological Survey Professional Paper 1395), by Snyder, J.P., U.S. Government Printing Office, 1987, Washington, DC
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12. H.S.Hopfield, "Two-Quartic Tropospheric Refractivity Profile for Correcting Satellite Data", Journal of Geophysical Research, Vol. 74, p. 4487, August 20, 1969.
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ACRONYM LIST

AOS	- Acquisition of Signal
ECF	- Earth Centered Fixed
ECI	- Earth Centered Inertial
FOV	- Field of View
GS	- Ground Station
LOS	- Loss of Signal
OATS	- Orbit Analysis Tools Software
OLES	- One Line Element Set
SDC	- Space Defense Center
sea	- self-extracting archive
TLES	- Two Line Element Set
WGS84	- World Geological Survey 1984

GLOSSARY

command-key: designation for a Macintosh procedure initiated using a two key sequence. A command-key is implemented by pressing and holding the ⌘ key (also shown as), and then pressing another key.

coverage time: the interval between Acquisition of Signal (AOS) and Loss of Signal (LOS).

elevation mask: for a ground station, the elevation mask defines the portion of the station's hemispherical horizon not visible to the station; it is the elevation above the horizon above which a satellite must rise before it can be viewed by a ground station.

herg: a unit of time measure commonly utilized in orbital mechanics; it equals 806.8120769 seconds and is the orbital period of an imaginary satellite rotating about the Earth at zero altitude.

isochrones: lines connecting points on the Earth's surface that have equal values of time duration of satellite coverage.

outage time: the interval between LOS and AOS.

revisit time: the interval between one AOS to the next AOS.

swath: the area on the Earth's surface swept out by the field-of-view of a satellite as it rotates around the planet and scans over the surface.

INDEX

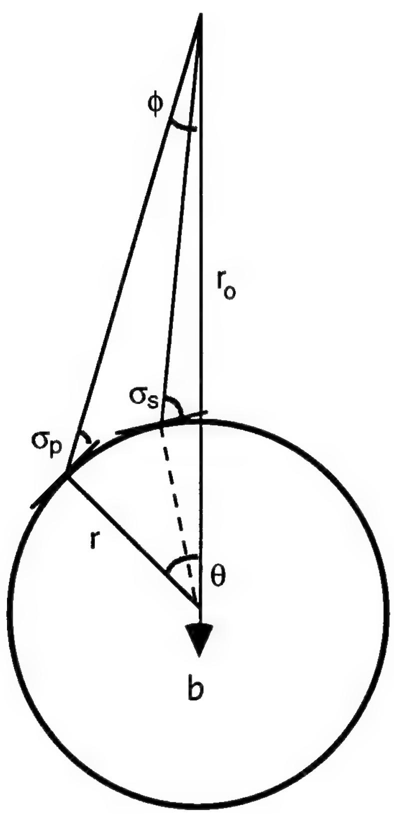
MENU COMMAND INDEX

See also the regular index in Section I.

APPENDIX A - SENSOR TERMINOLOGY

A.1 ANTENNA PATTERNS

Version 5 of the OATS software supports both nadir-pointing and non-nadir-pointing conical satellite sensor patterns. OATS also supports an annular satellite field-of-view, which is a variation on the conical sensor pattern wherein a conical "hole" exists centered in the antenna pattern. The sensor pattern is always symmetric about an axis known as the boresight direction. The viewing geometry for a nadir-pointing satellite is depicted in Figure A-1. In this diagram the boresight direction is Earth-centered, but this will not necessarily be the case when attitude data is used.



r	=	earth radius
b	=	boresight direction
r_o	=	satellite orbital radius
ϕ	=	cone angle
θ	=	earth central angle
σ_p	=	primary elevation angle
σ_s	=	secondary elevation angle

Figure A-1. Satellite Antenna Pattern Geometry

Where required under the **Plot** and **Coverage** menus, the user can define the sensor pattern by selecting an antenna type of cone angle, earth central angle, or elevation angle. For these cases, a single angle defines the sensor FOV. Program dialogs designate this single angle as the primary angle, even though no other angle is necessary. Selection of an antenna type that is annular requires specification of both the primary elevation angle and the secondary elevation angle. It is required that the secondary angle

specify the interior edge of the annulus and the primary angle specify the interior edge of the annulus. and OATS will sort these two data inputs in order to maintain the required relationship.

A.2 ATTITUDE TERMINOLOGY

Spacecraft attitudes and the orientation that they impart to an antenna sensor are implemented in OATS by specification of the sensor boresight direction. Three possible coordinate systems are available in which to specify the attitude, including:

- *Inertial System* (X,Y,Z) - The fundamental plane is the Earth Equator. The X direction lies in the fundamental plane in the direction of the Vernal Equinox. The Z direction is the North Pole. and Y = Z **cross** X.
- *Orbit Local Coordinate System* (x,y,z) - Where x is in the direction of the velocity vector, y is normal to the plane of the orbit, and z = x **cross** y
- *Perifocal Coordinate System* (X_W,Y_W,Z_W) - Where X_W points toward the orbit perigee, Z_W is in the orbit normal direction, and Y_W = Z_W **cross** X_W.

Within these three coordinate systems, OATS permits specification of satellite attitude in four ways:

1. Nadir Pointing

   The sensor boresight direction is toward nadir. For circular orbits this corresponds to the -z direction in the Orbit Local Coordinate System

2. Roll/Pitch/Yaw

   The Roll / Pitch / Yaw system allows the sensor direction to be specified as a rotation about the orbit normal coordinate system. When using this specification type, the sensor boresight is rotated by the roll, pitch, and yaw angles away from the -z direction. The rotation convention is taken in the following order: 1) pitch about y, 2) roll about (new) x, 3) yaw about (new) z. "New" x means the x direction after the pitch rotation, and "new" z means the z direction after the pitch and roll rotations. When the roll, pitch, and yaw angles are zero, the sensor boresight is in the -z direction.

3. Right Ascension / Declination

   The right ascension / declination system allows the sensor direction to be specified with respect to the inertial system X, Y, Z. The right ascension angle is measured in the equatorial plane from X in the direction of Y. The declination angle is measured from the X/Y plane in the Z direction.

4. Perifocal

   The Perifocal system allows the sensor direction to be specified with respect to the satellite orbit. The direction parameters are simply Xw, Yw, and Zw, as defined by the perifocal coordinate system above.

APPENDIX B - TIPS FOR PROCESSING WITH OATS

TIP # 1 - ADVANCED PRINTING TECHNIQUE

The Macintosh screen resolution of 72 pixels/inch is lower than what most printers can achieve. Printing a screen plot with an "as-is" resolution will result in significant granularity in the drawing. To reduce this problem and work with a higher printing resolution (more pixels per inch), the user can choose a smaller "percent reduction" (see Section 5.4). Maximum resolution and detail can be achieved with a LaserWriter (300 dpi) using a 25% reduction setting when printing. However, such a reduction can result in a hardcopy plot that is diminutive. Selective sizing of the Graphics Window that is being plotted such that it is set to be significantly larger than the display size of most monitors allows a normal sized final output page to be printed. DynaFace and OATS can work with this setup, but the user should understand that only a small portion of his oversize plot will show in the Graphics Window and that the full plot can be viewed in the Reduced View Window.

TIP # 2 - SQUARE GRAPHICS WINDOW

OATS is capable of supporting any size graphics window that can fit on the screen, but the user is advised that a square window is usually preferred. Rectangular windows are quite acceptable, and there may be some occasion (e.g. some variations on Mercator plots) where they might improve the readability of the plot. However, the user should note that non-square windows do introduce a distortion into the plots that can be confusing and which may not transport well to other applications.

TIP # 3 - PICTURE CROPPING

Maps and pictures drawn using OATS can be incorporated in other documents using the OATS **Copy** or **Cut** menu options, and then a **Paste** in the targeted document. Sometimes during this process the map borders may be large enough that an unacceptably large amount of white space is also copied along with the map if a **Select All** is used to specify the area copied. This is commonly the case when using a rectangular map projection with a square window. To alleviate the problem, it is possible to redefine the window size and border size and redraw the map; however, it is more efficient to eliminate the white space by cropping the picture before transfer. This is done by positioning the cursor a few pixels above and to the left of the OATS map. Push and hold the Apple ( ) key, and click and hold the mouse. Drag the cursor to a few pixels below and to the right of the map. This encloses the map being transferred in a minimized marquee, and selects this minimized area to be transferred. Then using **Copy Pixels** and **Paste** will not move the excess white space to the user's document.

TIP # 4 - GHOST LINES

One of the peculiarities of OATS is that it can leave a "ghost line" when plotting any FOV under selected circumstances. This problem can occur when plotting an FOV where the attitude of the spacecraft is such that the outline of the FOV extends beyond the visible limb of the Earth. This orientation produces a normal FOV outline that typically resembles a bell-shaped figure. If the sensor is annular, and the outline of the inner hole also extends beyond the Earth's limb, a ghost line can occur. The total FOV is derived by computing the FOV of the primary sensor angle and subtracting out the FOV of the secondary sensor angle. Ghost lines occur because the subtraction is imperfect, and a few pixels appear along the edge of the interior hole that follows the Earth limb.

TIP # 5 - LIMB GRAZING FOVs

OATS has a known problem with drawing FOVs for sensors that are oriented at an extreme angle away from nadir pointing. Often in such cases, the FOV locus is made up of a part where the sensor pattern intersects the Earth and a part that is the local horizon. In cases where only a small fraction of the sensor pattern intersects the Earth, OATS sometimes incorrectly computes the horizon. While this error has not been corrected in version 5, its occurrence is detected by the software. When the error condition is detected OATS approximates the FOV by connecting the ends of the intersection locus. This error is most likely to occur when combining large sensor cone angles with large off-nadir attitudes. It will not occur for nadir viewing sensors.

APPENDIX C - REVIEW OF ORBITAL ELEMENTS

This users manual is not an appropriate vehicle for a comprehensive discussion of orbital elements or the mathematical models behind the various orbit propagators; however, the authors do furnish this section as a *basic* explanation of the terminology used to specify orbital elements. For an in-depth review of the derivations of the orbital elements, the user is directed to Reference 14. For a better understanding of the orbit propagators, see Section 6.1 and the references cited therein. The review of orbital element terminology applies throughout the document, but is especially relevant to the Section 10.1 discussion of orbital elements and the Section 6.3 discussion of the entry dialogs for orbital elements.

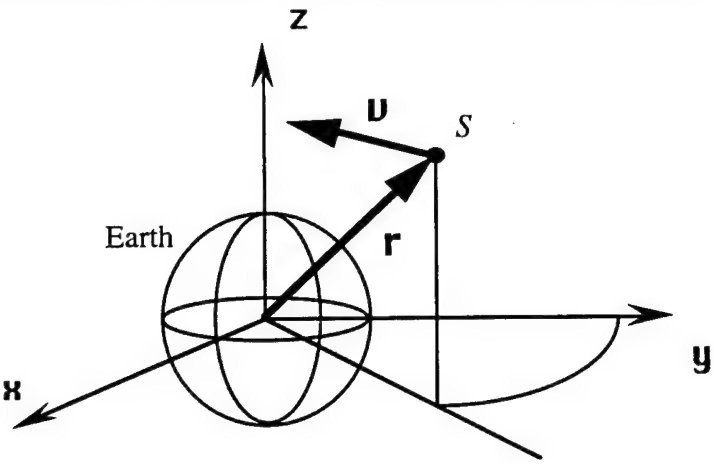


Figure C-1. Cartesian Representation of a Body in Space

The position of any satellite in space, *S* can be represented by its position vector **r**(t) as shown in Figure C-1. If **r** is represented as the sum of its three-dimensional Cartesian vector components:

$$\mathbf{r}(t) = \mathbf{x}(t) + \mathbf{y}(t) + \mathbf{z}(t) \qquad 10\text{-}1$$

then any motion of the body can be represented as the time rate of change of each of the vector components, or the velocity vector **v**(t):

$$\mathbf{v}(t) = \frac{d\mathbf{x}(t)}{dt} + \frac{d\mathbf{y}(t)}{dt} + \frac{d\mathbf{z}(t)}{dt} = \dot{\mathbf{x}}(t) + \dot{\mathbf{y}}(t) + \dot{\mathbf{z}}(t) \qquad 10\text{-}2$$

This simple formulation of orbital elements is the Cartesian state vector used by the RUK12 propagator. Orbital elements are specified by **x**, **y**, **z**, and **x**dot, **y**dot, and **z**dot at a known point in time. The RUK12 propagator then takes the known position and velocity, combines them with the equations of motion, and repetitively projects the position and velocity at some small increment of time Δt beyond the known time.

Only two other factors are required to specify the RUK12 orbital element set. The first is a flag that defines if the supplied position and velocity vector components are given in the ECI or ECF coordinate frame (see Section 6.2). The difference between the two is a rotational coordinate transformation that accounts for the difference in the placement of the zero point in time. aswell as the rotation of the ECF system The second factor is an orbit decay term, showing how much the orbit is shrinking over time. Decay rates for typical stable orbits are near zero, and most often are provided as a small constant value if they are important at all. Decay rates can become large and non-constant for very low atmosphere-grazing orbits or in the presence of transient external forces like solar flares. In addition to the conceptual simplicity of the orbital elements, the RUK12 propagator has an advantage over the other available propagators in that it can propagate any trajectory. These advantages are offset by the fact that this propagator is computationally intensive and much slower than the other options available.

A somewhat more common approach to the problem of specifying the orbital elements for a spacecraft is to assume that the satellite is gravitationally bound to the Earth. Such a satellite follows a closed path that is a conic section called an ellipse. This simplifying assumption transforms the problem of specification of orbital parameters to one of specification of parameters that define the geometrical shape and orientation of the ellipse. Other non-closed conic section orbits are of course physically possible (e.g. parabolic or hyperbolic paths); however, with the exception of the RUK12 propagator, OATS orbit propagators are not relevant to such orbits. There are always minor deviations from a true ellipse in a satellite orbit--deviations that are caused by real-world factors like atmospheric drag, solar radiation pressure, deviations of the Earth from a spherical shape, non-uniformities in gravitational pull on the satellite, or forces originating in the satellite itself like engine firings or outgassing. Some of the propagators available in OATS (e.g. SGP4) account for the largest of these deviations, but over time there will always be degradation of an orbit and evolution of the orbital elements. This is why every set of orbital elements is furnished with an epoch at which the elements were calculated and at which the elements are correct. The further in time that an orbit deviates from the source epoch, the larger the errors that can be expected to be found.

An ellipse is defined as the collection of points in a plane, such that for each possible point the sum of distances from two fixed points to the ellipse point is a constant value. The basic geometry of an ellipse is shown in Figure C-2. The center of the Earth will always occupy one of the defining points for the ellipse, known as a focus ($\mathbf{F}_1$). The other focus ($\mathbf{F}_2$) is empty, but for most real orbits this focus lies within the diameter of the Earth. The distance **AB** is the greatest diameter of the orbit, called the major axis. Both foci are equi-distant from the center **X** and located on the major axis. The distance **CD** is the smallest diameter of the orbit, called the minor axis. **AB** and **CD** are the axes of symmetry of the ellipse, and meet at the center at **X** and cross at a right angle to each other. The distance **AX** or **BX** is known as the semi-major axis, **a**. This distance is also the mean distance of the satellite from the center of the Earth at focus

F_1. The stretching (or flattening) of the ellipse is measured by a unitless quantity called eccentricity, **e**. If **c** is the distance from the center to a focus, then:

$$e = c / a \quad \text{or} \quad c = a * e \tag{10-3}$$

A circular shaped orbit is merely a special case of the ellipse where **e** = 0. If *S* represents a satellite in Figure C-2 moving along its orbit at an arbitrary time **t**, then the position of the satellite can be specified by the angle **f**, the true anomaly.

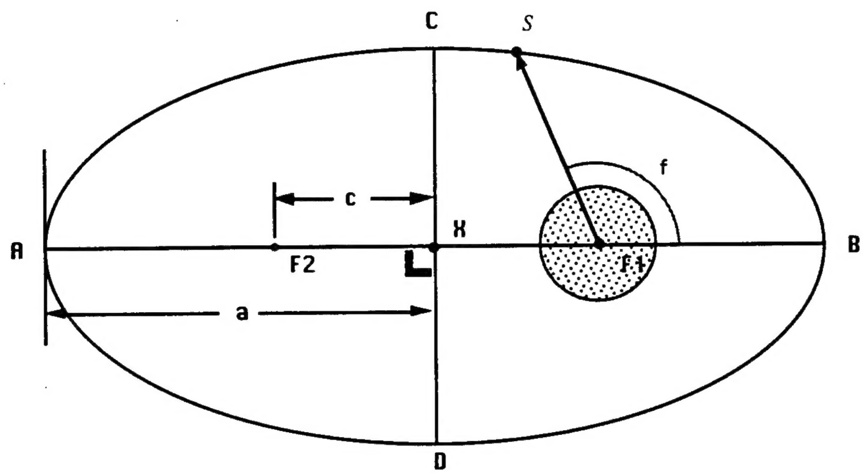


Figure C-2. Basic Geometry of an Orbit Ellipse

While the semi-major axis, eccentricity, and true anomaly are adequate to define the shape of the orbit they do not determine the spatial or temporal orientation of the ellipse relative to the Earth. The classical solution to this problem is to define three angles--an inclination i, a right ascension Ω, and the argument of perigee ω--as shown in Figure C-3.

For Figure C-3, the **xyz** Cartesian coordinate system is defined such that the **xy** plane coincides with the Earth's Celestial Equator (equatorial plane) and the **+x** axis is aligned with γ, the Vernal Equinox. Also known as the first point of Aries, γ is the point on the celestial sphere where the ecliptic (apparent path of the sun) crosses the celestial equator in the spring. The inclination angle i is the angle between the orbit plane and the Earth's equatorial plane. Inclination is measured around the line of intersection of the equatorial and orbit planes, also known as the line of nodes. This line connects the ascending node **AN** (the point on the equator where the satellite passes from the southern hemisphere to the northern) to the descending node **DN** (where the satellite passes from northern to southern). The angle Ω is the right ascension angle between the vernal equinox and the ascending node as measured in the equatorial plane. The third angle ω is the argument of perigee. It is defined relative to the perigee (perifocus), or closest

approach to the central body around which the satellite is orbiting. The perigee is labeled point **B**. The argument of the perigee is the angle from the ascending node to the perigee measured in the orbital plane.

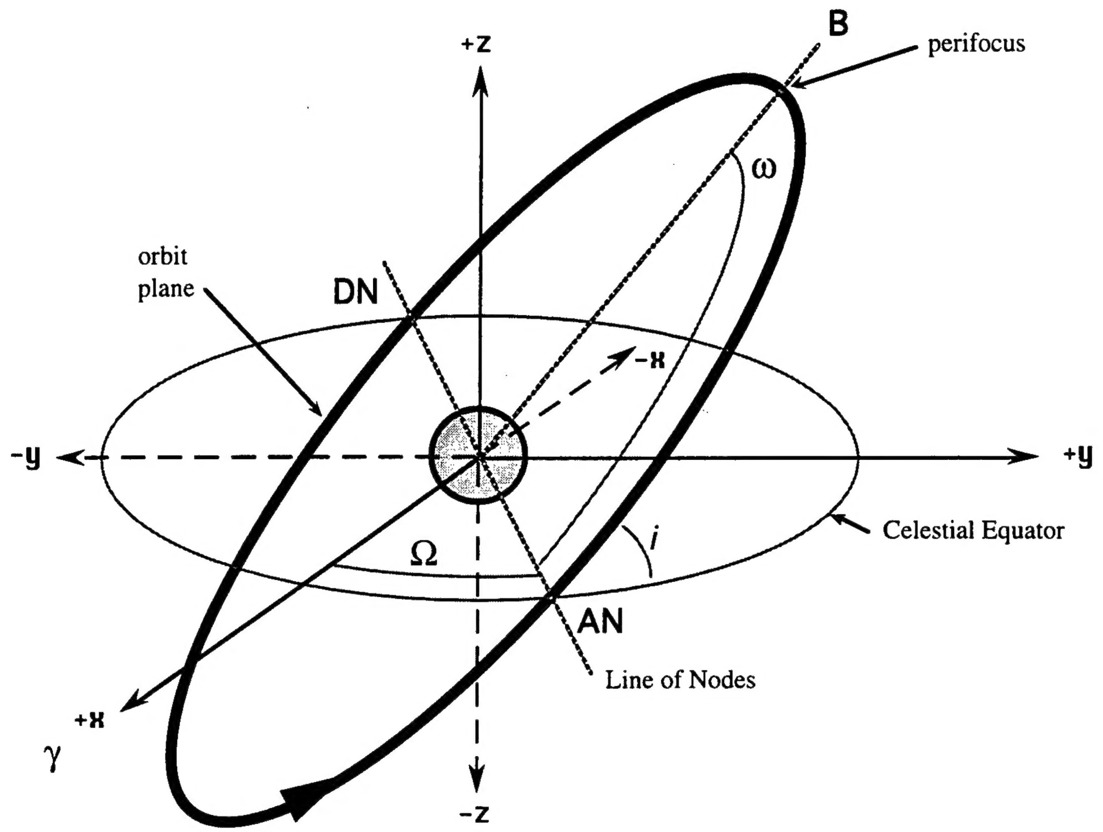


Figure C-3. Orientation of Orbit Ellipse Relative to Earth

The six coordinates of the ellipse, **a**, **e**, f, i, ω, and Ω are sufficient to completely specify an orbit, and can be used in conjunction with an epoch and a flag designating an ECF or ECI coordinate system for the orbital elements for the J2 propagator. However, these often do not represent the easiest formulation of the orbital elements to work with.

Figure C-4 presents an alternative geometrical representation of the orbit ellipse which is intended to complement the basic schematic presented in Figure C-2. In this figure, a circumscribing auxiliary circle is placed around the ellipse. **P** now designates the point of perigee. The geometry shows the auxiliary angle **E**, eccentric anomaly, which is introduced as an intermediate computational and comprehension step. Eccentric anomaly is defined as the angle measured in the orbital plane from the axis of perigee passage to a line containing the center and another point defined by the projection of the moving vehicle in the axis perpendicular to the perigee axis upon an auxiliary circle circumscribing the ellipse of satellite motion. In

Figure C-4 the projection of the satellite on the circle is a fictitious satellite S_m . The mean angular rate of the satellite, called mean motion, is usually symbolized as **n**. Mean motion is the angular rate of the fictitious satellite as it travels around the circumscribing circle. By definition **n** is an easily specified constant value, whereas the true angular rate of the satellite around an ellipse varies with position on the ellipse. The mean anomaly, **M**, is another auxiliary angle that physically represents the angular displacement of the fictitious satellite and the mean angular rate of the satellite. The quantities **n** and **M** represent the last of the orbital elements typically used as inputs for the J2, SGP4, and PPT2 propagators. Useful relations of these two quantities are as follows:

$$\mathbf{M} = \mathbf{E} - \mathbf{e} * \text{sine}\ \mathbf{E} \qquad 10\text{-}4$$

$$\mathbf{n} = 2\pi/\mathbf{period} = \sqrt{\left(\mu/_{\mathbf{a}^3}\right)} \qquad 10\text{-}5$$

where μ is the combined mass of the satellite and the Earth, usually rounded to just the mass of the Earth.

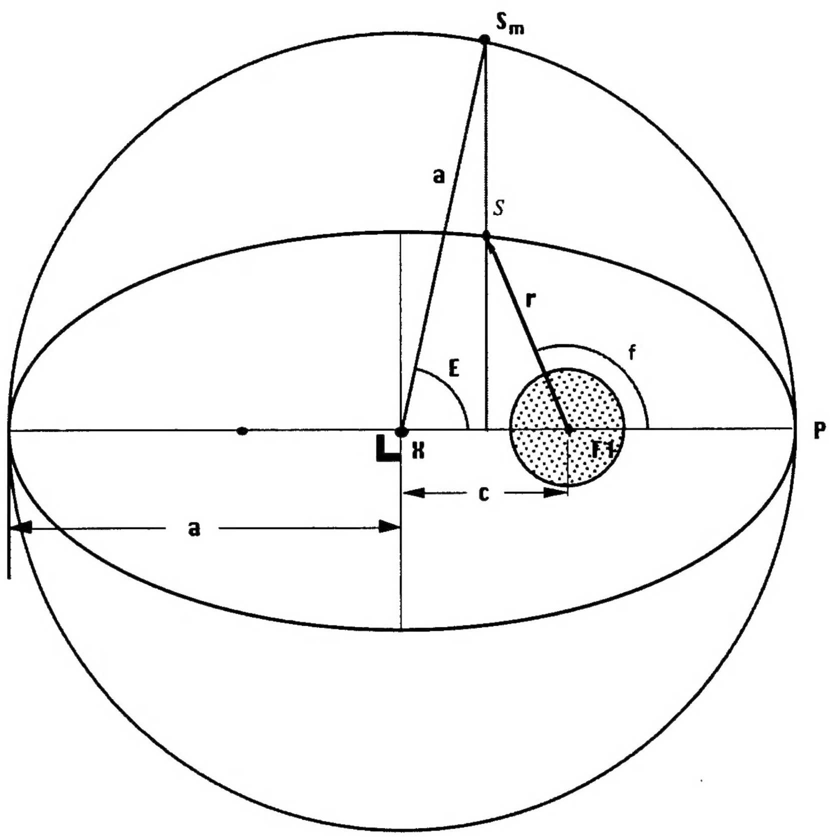


Figure C-4. Geometric Representation of Mean Motion